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SOME UNEXPLORED FIELDS IN ELECTRICAL ENGINEERING.*

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IN discussing the subject of the unexplored fields of electrical engineering, we must consider as belonging to the realm of the electrical engineer, all those phenomena of electricity that are of importance to man: those which are beneficial and useful, and utilized in doing the work of the world, and also those phenomena which are harmful and destructive, and therefore to be guarded against.

It is obviously impossible to touch on all the unexplored fields of electrical energy, for while electrical engineering is not in its infancy any more, nor has been for some time past, there are many more unexplored fields than there are explored fields of electrical engineering; and even in those fields which have been most carefully investigated we find still many unknown regions. A lot of work has been done along many lines since the early days of electrical engineering and a lot of different fields have been uncovered; but there are larger fields still unexplored and there are regions that are still unknown.

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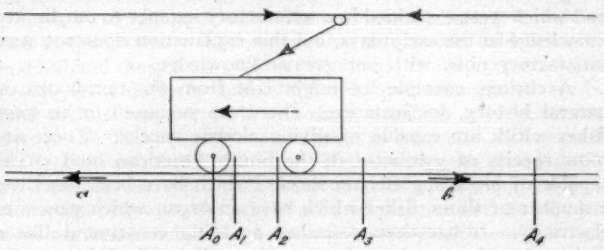
To illustrate—there is no simpler and apparently better known phenomenon than the resistance of a conductor. A conductor has a definite resistance which varies with the temperature, etc. With the alternating current the resistance apparently increases in large conductors, because the current flowing in the conductor is not uniform throughout the entire section, but, by the screening effect of the magnetic field inside the conductor, the current density inside of the conductor is less than it is on the outside. We can calculate the phenomena of the lack of uniformity of the current density in the conductor for the case where the current density is not yet very un-uniform, as if in the centre of the conductor the current density is only from 5 to 10 per cent. lower than on its periphery. We get an approximation which is satisfactory for all purposes of electrical engineering, and shows us, how large a conductor we can use without serious waste of conductor material. Then there is the other extreme, where the current density in the middle of the conductor is practically zero, and the current is limited to a thin shell on the outer surface as in the rail return of the single-phase railway, or in ordinary conductors at very high frequencies, as with lightning discharges. This case we can also calculate, determine the current distribution in the conductor, the apparent penetration and the effective resistance of the conductor, with an approximation as close as our knowledge of the constants of the material, the conductivity and permeability, permits. But when you come to the intermediate and probably most interesting case, where there is current even in the centre of the conductor, but a material difference in the current density betwen the outside and the centre of the conductor, we find as solution an infinite series, which in this case converges so slowly as to be practically useless, and this case thus is still practically unexplored.

Another unexplored phenomenon of every-day occurrence: there are many thousands of trolley cars running all over the country with a direct current supply of about 500 volts, and rail return. While the car passes along the track, the current flows from the wheels down into the rails, and then in the rails to the station, as sketched diagrammatically in Fig. 1. At the point A_0 the current enters the rail from the wheel. To the left of this point, it flows towards the left, as indicated by the arrow a. To the right of A_0, it is supposed to flow towards

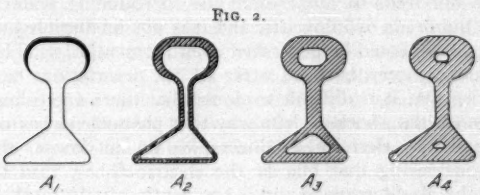
the right, as indicated by b, and at the point A_0 the current in the rail thus is supposed to reverse. However, the current cannot instantly reverse in the entire rail section, but the same screening effect of the magnetic field in the conductor, which causes unequal current distribution with an alternating current, makes it impossible for the current inside of the conductor to

FIG. 1.



reverse instantly, and in the first moment, the reverse current b thus flows only on the very top surface of the conductor, and only gradually penetrates deeper into the conductor, and before the current flows uniformly throughout the entire rail section in the new direction b, the car has moved hundreds or even thousands of feet. Thus, the current distribution in the rail

FIG. 2.



behind the moving car, in the successive sections A_1, A_2 . . . is as indicated approximately in Fig. 2, where the black or shaded portion of the rail shows the section in which the current has already reversed, the unshaded portion the unreversed part, that is, that part, in which the current still flows in opposition to the resultant current flow, is running forwards instead of backwards. The obvious result is an increase of the effective resistance of

the railreturn, which immediately behind a high-speed car may be very considerable. Still this phenomenon, which occurs daily all over the country, has never been investigated, not even been recognized in its existence.

In some fields of electrical engineering or of electrical science we might almost say that we know less now than we knew, or rather believed we knew, a quarter of a century ago. There are things which had been investigated a quarter of a century ago and which were explained in a satisfactory manner to our limited knowledge in the early days, but this explanation does not seem satisfactory now, with our greater knowledge.

A curious example we might cite from the text-books on natural history, for instance. There are supposed to be some fishes which are capable of giving electric shocks. There are some species of gymnotus in the South American mud creeks capable of imparting electric shocks, which have been described a number of times, fishes which have an organ which generates electricity. It has been described as being constituted like a Volta-pile, of a number of successive cells. That theory was quite acceptible twenty-five years ago, but is not satisfactory now. To give a severe shock, would require about 500 to 1000 volts, and it is not intelligible how such voltage could be generated in the conducting animal tissue, without being short circuited. Furthermore, the fish is immersed in water, which is a fair conductor, especially sea water, and 500 volts or more would produce hundreds of amperes in the surrounding water, representing hundreds of kilowatts, and it is not intelligible how such a large power could be generated even momentarily. Thus here we have a mystery, because, after all, the descriptions have been so concise that it is difficult to doubt that there are fishes which can give electric shocks. Just why that phenomena has not been investigated by electrical engineers, we do not know, especially when considering that one of the electric fishes, raja torpedo, lives in the Mediterranean and is frequently caught on the Italian shores, as claimed, thus is within easy reach of engineers.

But we do not need to go so far from home, right at hand we have some of the most important uninvestigated phenomena of electricity. The thunder storm, the lightning, and so forth. In the early days, lightning was explained as the discharge of the clouds. The clouds are positively charged, and the ground

is negatively charged, and the spark jumps from the cloud to the ground. Speculations were made as to how the clouds became charged, and as then the only method of producing electricity was by friction, it was said it might be the friction of the vapor through the air, or the rain drops through the air, or some other form of friction. That explanation used to appear satisfactory, but with our present knowledge of dielectric phenomena, it is not satisfactory any more.

It was thought that lightning was the discharge from the cloud to the ground. That means that the electric field between the cloud and the ground must be beyond the breakdown strength of air. In a uniform field, the breakdown strength of air is about 75,000 volts per inch, or nearly a million volts per foot. Even if the cloud is only 1000 feet above ground, this would require a thousand million volts. If there were an electrostatic field between the cloud and the ground of a thousand million volts extending over the whole area of the thunder cloud, this would represent such an immense amount of electric energy, that it is inconceivable how any reasonable source of energy can produce it; how it can exist without having a destructive effect far beyond anything known of lightning. Furthermore, a uniform field cannot well exist between clouds and ground, on account of the unevenness of the ground surface.

Let us look into another conception, not a uniform electrostatic field, but an un-uniform field, like that of the discharge between points. With long striking distances between points, the average gradient is about 170,000 volts per foot. This would require only 170 million volts between a cloud 1000 feet high, and the ground. This would be more reasonable. It would not require such an unreasonably vast amount of stored electric energy. But we know that in such an un-uniform field the spark is preceded by a brush discharge covering more than half the distance. Thus, lightning should be preceded by a brush reaching down from the cloud and up from the ground, for several hundred feet. Now such an enormous brush has never been observed, and is inconceivable; the brush discharges occasionally observed at points during storms are only a few inches long. Furthermore a 300-foot brush is inconceivable, because the resistance of the ground is not low enough to conduct the energy necessary to maintain such a brush discharge.

Furthermore, most of the lightning discharges are not between the cloud and the ground, but are internally in the clouds, frequently reaching the length of several miles. So you see the explanation of the lightning as a spark discharge similar to the discharge of the friction machine appeared plausible in the early days, but with our present knowledge it is not tenable any more.

We cannot consider the lightning discharge as a simple electric rupture, in the same way that an overloaded beam may break mechanically, but as an equalization of internal stresses, about as a piece of hot glass that is rapidly chilled, and thereby full of internal compression and tension strains may suddenly break all over, by the internal stresses. So with our present knowledge, we must consider as the most probable explanation —although not certain by any means—that the lightning discharge is the phenomenon of the equalization of internal electric stresses in the cloud, and is analogous to the splintering or breaking of an unevenly stressed brittle material, like glass.

The question then is, how do those uneven electrostatic stresses originate in the cloud, and how do they reach such values as to cause internal equalization by rupture? If there has been produced a very highly unequal distribution of voltage in the electrostatic field of the cloud, it is easy to see how a discharge can pass along miles of cloud, without such unreasonably great potential differences as would be required for a direct discharge across space, just as from a scratch in a poorly annealed glass plate cracks may run all over the plate, splintering it in all directions. Assuming that the potential distribution in the cloud becomes very uneven. If then at some point the potential gradient becomes higher than the disruptive strength of air, at this point a local disruptive discharge occurs, perhaps only a few inches in length. This discharge equalizes the potential gradient within its path, and thereby increases the gradient at the ends of the discharge. If this gradient is already fairly high, it rises beyond the disruptive strength of air, and thereby the discharge extends farther along the discharge path, but by the voltage equalization resulting therefrom, still further increases the potential gradient ahead of the discharge, and in this manner the equalizing discharge extends farther and farther, possibly for miles, side discharges issue from it or run into it,

until finally cloud regions are reached, where the initial potential gradient is very low, and the discharge gradually tapers down.

But where does the initial voltage come from, and how does it become uneven?

It is not so difficult at least to make a preliminary estimate of the building up to very high, and uneven voltage distribution in the cloud, as soon as you have assumed some initial voltage. We do not know where the initial voltage comes from, but we must accept the fact that there is normally a voltage gradient in the air, a potential difference between different altitudes which may amount to a hundred volts or more per foot. In the air 100 feet above the ground, there may be a potential difference against ground amounting to thousands of volts. If you bring a wire up to there you do not carry a current down, but you merely carry the ground potential up, but by a carefully insulated electrostatic voltmeter you can measure these potential differences. Possibly, this potential gradient in the atmosphere may even be of cosmic origin: the earth having a high negative potential against our solar system, against the universe, which would mean that there must be a positive voltage gradient from the surface of the ground into space.

If condensation takes place in the higher regions of the atmosphere, rain-drops form, minute drops at first, which necessarily must be at the potential of the air in which they form. That means they have a potential difference against the ground, and therefore an electrostatic charge against the ground corresponding to this potential difference. Assuming now that many of these minute rain-drops conglomerate to larger drops, it means, that many small condensers conglomerate to one condenser, which is somewhat larger in capacity, than each component, but very much smaller in capacity than the sum of the capacities of its components. But it contains all the electrostatic charges of the rain-drops, and at the much smaller capacity, the same charge gives a higher potential difference: Suppose a thousand small rain-drops conglomerate into one large one. This has ten times the capacity but 1000 times the charge, hence a hundred times the voltage. Conglomeration of minute drops into larger ones thus must give a great increase of potential difference against ground.

We know the clouds are not uniform in density, and where

the density is greatest conglomeration of condensed drops takes place to a much greater extent, building up to a much higher voltage, and thereby between the parts of the cloud of different density, the light and the dark portions, potential differences must appear and increase with increasing condensation, until somewhere the disruptive gradient is passed, equalization occurs by a lightning discharge, and then the same play repeats again and again.

Lightning discharges then are the result of the voltage unequalities produced in the clouds by the unequal rate of conglomeration of rain particles due to the unequal cloud density.

In agreement with this is, that heavy lightning strokes are usually followed by a heavy down-pour of rain: in reality they are preceded and caused by it, but it takes time for the rain-drops to come down.

Let us assume now that the process is reversed, and after conglomerating to high voltages the rain-drops evaporate again. Since gases apparently do not carry electrostatic charges, the rapidly dwindling rain-drop retains its entire charge, hence must rise in potential, and finally must discharge, and this progressive evaporation of the rain-drops must also result in the building up of potential differences and therefore the formation of lightning, and this may explain the two forms of lightning, that accompanying rain-storms and thunder-storms, and the so-called "heat" lightning.

The former is the result of condensation and conglomeration, the latter the result of evaporation of rain-drops.

You see then, that in this field, which is not merely of theoretical interest, but of high industrial and general importance, our knowledge is still very limited, it is a fairly unexplored field of electrical engineering and electrical science. It is a branch of electrostatics, of the phenomena of the dielectric field. The phenomena of the dielectric field we cannot very well call unexplored, because there has been a great deal of investigation in the early days, and volumes have been written on it. Many of us may still remember the early days when the text-books of electrical engineering started with the theory of the distribution of the electric charge, investigated the electric density on an ellipsoid and all that sort of thing. All this has now pretty well vanished from electrical engineering text-books. With the development of electrical engineering, electrostatics became of

less interest and were thus neglected. Only in recent years, when we have in transformers and transmission lines reached voltages higher than in almost any electrostatic machine, and those not of a negligible power, but of a very large power, the field of electrostatics has become a very important one, and has to be studied again.

We now find that in the study of electrostatics, the conceptions of the work of former days is untenable, from our present point of view; we cannot conceive of the dielectric phenomena as a charge on the conductor surface, we know there is not an electric charge on the conductor, the dielectric energy resides not on the conductor surface, but is in the space around the conductor, in a dielectric field, and the so-called "charge" is nothing but the termination at the conductor surface, of the electrostatic field in space. It is the electrostatic or dielectric field, which we must consider as representing the phenomena of electrostatics, in the same way as Farady has shown us with the magnetic field.

The old conception of the electrostatic charge on the conductor has been the cause of the far greater difficulty which we find in dealing with even simple phenomena of electrostatics, compared with the simplicity, with which even apparently complex phenomena are treated by the conception of the lines of magnetic force.

We must then abandon the conception of the theory of electrostatics of the early days—which still largely is used in theoretical text-books—as incorrect and useless. Capacity then is not the capability of the conductor to store electric quantity, but is the ratio of the number of lines of dielectric force, to the electromotive force which produces them, just as permeance is the ratio of the number of lines of magnetic force, to the magnetomotive force which produces them, the "charging current" is no more a current charging the conductor with electricity, than the "inductance voltage" is a voltage charging the conductor with magnetism; the former, as "capacity current" supplies the energy stored in the dielectric field, just as the inductance voltage supplies the energy stored in the magnetic field, and dielectric and magnetic phenomena are very largely analogous and treated in the same manner, and with the same simplicity.

This was not possible with the conception of electrostatic

charges, and even simple problems, as the calculation of the capacity and the mutual capacity of parallel conductors, become so complicated that the most satisfactory method of their calculation was not to calculate the capacity at all, but calculate the corresponding inductance, and derive the capacity by the relation, that capacity times inductance equals the square of the velocity of propagation, which in space is the velocity of light (3×10^{10}).

You see then, that in this field, which is of the highest industrial importance now, where we have in transmission lines reached voltages which approach those of lightning, we are only just in the beginning of an intelligent understanding, an insight into the phenomena.

Now we come to another field, not very far distant from the previous one: *Conduction of gases and vapors.* It is a field in which an enormous amount of investigation has been carried on in the last years by the physicists, so that it may almost be called the best explored branch of modern physics. Unfortunately, there has been very little, if any, benefit from all this work, to the electrical engineer. If you ask some simple engineering question, as for instance, you have a Geissler tube, 4 cm. diameter and 10 m. long, filled with nitrogen gas under 0.1 mm. pressure. What will be the voltage required to pass a current through the tube, what will be the amount of light given by it, and how will the voltage vary with the current and with the gas pressure? The answer is unknown, in spite of the enormous amount of scientific work done in gas conduction, nothing is known even of the most elementary electrical questions, the relations between voltage and current, dimension and gas pressure.

We have a great mass of physical studies on gas conduction, but naturally the engineer cannot have much confidence in these scientific investigations on "how" and "why" and "wherefore" of the phenomena, if the question "what are the phenomena" remains unanswered, is apparently overlooked.

We now have some data on the electrical constants of gas conduction, and our knowledge is rapidly increasing by the work of the engineers, who finally, as in other fields of research, have despaired of ever getting the scientific investigators to drop metaphysical speculations long enough to determine physical facts, have started to investigate the engineering facts themselves.

The same applies to arc conduction, though arc conduction has been investigated by the engineers for a much longer time, and more is known about it.

In the arc, the voltage required to maintain an arc of constant length, decreases with increase of current. This voltage consists of two parts, one, which is constant and independent of current and arc length, the "terminal drop," and one, which decreases with increase of current and thus of arc stream section,

FIG. 3.

Oscillogram of Geissler tube, 0.1 amp., 3000 volts: upper curve, current; lower curve, voltage.

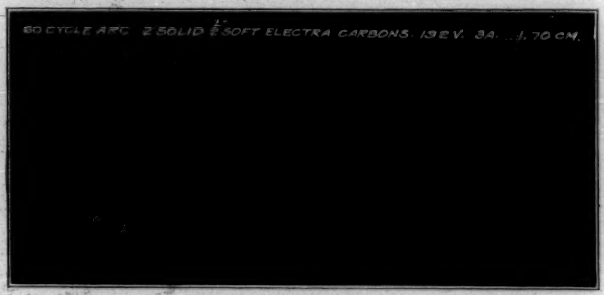
and increases with the arc length, and is of the nature of a voltage consumed by a resistance, the "stream voltage."

In the Geissler tube we also have a terminal drop and a stream voltage, but their proportions, and their variation seem to be very different from those in the arc. The terminal drop decreases, and the stream voltage increases with increase of gas pressure, so that the sum of both, or the total voltage consumed by the Geissler tube, is a minimum at some intermediate gas pressure—which minimum voltage gas pressure depends on the proportion of terminal drop and stream voltage, and thereby on the length of the tube.

However, the terminal drop seems not to be independent of the current, but to increase with increase of current, while the stream voltage—which is proportional to the length of the stream—seems to be practically independent of the current within a wide range. The voltage wave of an alternating Geissler tube discharge thus is characteristic, but entirely different from the characteristic voltage wave of the alternating arc. The former is shown in Fig. 3, the latter in Fig. 4.

Much of the work done on arc conduction is worse than useless, by unjustified generalization. Too often investigators have taken a pair of carbon terminals—since carbon terminals

FIG. 4.



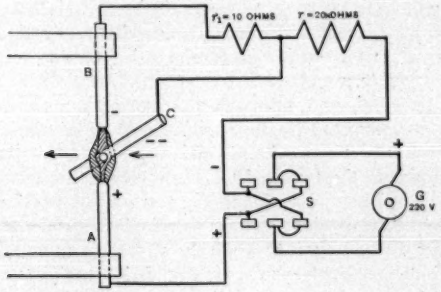
Oscillations of carbon arc: upper curve, voltage; lower curve, current.

are mostly used in arc lamps—have put various things on them, and then written a treatise on "the arc," without ever realizing, that whatever applies to the carbon arc, does not necessarily apply to any other arc.

The conductor in the Geissler tube is the gas which fills the space between the electrodes, and the material of the latter therefore of secondary importance, but the phenomena, as the voltage, the color and the spectrum of the light etc., essentially depending on the nature of the gas in the space between the electrodes, and on its pressure. In the arc, however, the conductor is a stream of electrode vapor, the material of the electrode therefore of fundamental importance on the voltage, luminosity, color and spectrum of the arc stream, while the

surrounding gas is of secondary importance only. The conducting vapor stream, or "arc stream," usually is at the boiling point of the electrode material. The carbon arc thus is the hottest arc. The dielectric strength of gases decreases with increase of temperature, and at the temperature of the carbon-arc stream has fallen below the voltage drop in the arc stream, so that in the carbon arc all the phenomena resulting from the dielectric strength of the vapor stream are absent, since the surrounding air has a disruptive strength less than the supply voltage of the arc. Nearly the same is the case with a few other very hot arcs. The carbon arc thus is not a typical arc, but is one of the extremes in a series of arc conductors, of which the other

FIG. 5.



extreme probably is the mercury arc, as the coldest arc. The latter thus gives the phenomena of the dielectric strength of the arc stream most pronounced.

In a general investigation of a class of phenomena, the first problem is to select reasonably typical conditions, and afterwards extend the study to the extremes. In the study of arc conduction, the use of the carbon arc as typical arc thus is no more justified, as it would be in the study of the phenomena of the melting point and the boiling point to select carbon as typical material.

This appears obvious, but very frequently has not been realized.

As the phenomena of arc conduction essentially depend on

the temperature of the arc stream, that is, the boiling point of the electrode material, typical conditions we can expect only from electrode materials having boiling points intermediate between the extremes, carbon and mercury. Such are many metals, as iron, copper, etc. The iron arc thus is a typical arc, but not so the carbon arc.

In the study of a typical arc, we find that the vapor stream, which conducts the current, issues from the negative terminal, as shown by its spectrum, and by the character of the arc: the latter depends on the material of the negative terminal, but is unaffected by any change of the positive terminal. The vapor conductor of the arc is moving rapidly from the negative terminal towards the positive, and is a conductor in the direction from the negative terminal to any point reached by the arc stream, which is positive towards the negative arc terminal, but is non-conducting with regard to any body negative towards the negative arc terminal. Thus, if I draw an arc between two iron or copper terminals A and B, with A as positive and B as negative terminal, and approach the arc with a third terminal C, which is connected to the positive side A of the circuit, as soon as I touch the arc flame, the arc leaves the terminal A and goes over to the terminal C. If, however, the terminal C *is* negative, as in Fig. 5, even much more negative than the negative arc terminal B, I may immerse the terminal C into the arc stream, for instance, by passing it through the stream from one side to the other, as indicated by the arrows in Fig. 5, but the arc stream does not leave the negative terminal B and goes to the more negative terminal C, that is, the arc stream is non-conducting towards negative C, but is conducting towards positive C. That is, the arc stream is a unidirectional conductor, and therefore can be used, and is extensively used for rectification.

In the experiment illustrated by Fig. 5, if I raise the voltage between C as negative and A as positive sufficiently high, that is, beyond the disruptive strength of the gap from C to A, the arc will be started from C to A by a disruptive spark.

The voltage range, within which an arc stream is non-conducting towards a negative body, or, as usually called, the "rectifying voltage range of the arc stream," is determined by the disruptive strength, and thus is a function of the temperature. Hence, it is many thousand volts with the low temperature mer-

cury arc, is still several hundred volts with the iron or copper arc, but vanishes below the temperature of the carbon arc, and the latter thus does not show any more the unidirectional conductivity of the arc stream to any marked extent, thus is an exception, and not a typical arc.

As in arc conduction the conductor is the unidirectionally moving electrode vapor stream, this vapor stream has first to be produced, by the expenditure of energy, before arc conduction can begin. Thus an arc has to be "started" by some of the various ways of producing the arc conductor, as by bringing the terminals into contact, or by passing an electrostatic spark between the terminals, etc. For the same reason, in an alternating current arc at every half wave a new arc stream has to be started, in opposite direction from that of the preceding half wave of current, and the supply voltage thus must be high enough to jump a static spark across the arc terminals through the residual hot vapor of the preceding half wave. This voltage is low with the carbon arc, but becomes very high with lower temperature arc. Even in the carbon arc, however, Fig. 4, the starting voltage peak is shown at the beginning of each half wave.

Entirely different from arc conduction apparently is the conduction of the Geissler tube and of the electrostatic spark. Geissler tube conducton and electrostatic spark, however, apparently are the same phenomenon, differing only by the difference of gas pressure. It appears startling to think, that the brilliant, noisy static spark, and the noiseless diffused Geissler tube glow are the same phenomenon. However, by gradually changing the gas pressure, the one gradually changes into the other.

The electrostatic spark, as produced in air under atmospheric pressure, passes between the terminals in an irregular shape, as a sharply defined thin zigzag curve of very high brilliancy and with a loud noise. If now we gradually lower the air pressure in the space in which the spark takes place, we find the spark gets less and less noisy and less brilliant, becomes thicker in diameter, less sharply defined, straighter; then the noise vanishes altogether, the spark thickens out still further, the brilliancy continues to decrease, its outside becomes more fluffy and finally surrounded by a kind of a penumbra, and finally the discharge uniformly fills the entire space as a uniform steady glow

of low brilliancy, which frequently shows the typical striations of the Geissler tube. Increasing air pressure again gradually changes the phenomenon from the steady noiseless Geissler tube glow of low brilliancy to the noisy thin spark of high brilliancy. Increasing the pressure still higher, above atmospheric, the spark becomes still more noisy and thinner, and more brilliant.

Thus the difference between the usual static spark and the Geissler tube glow is one of degree only, but not of quality. However, even this is largely due to extraneous conditions.

When speaking of the electrostatic spark, we usually think of the short-circuiting spark, that is, the spark which, when passing between the terminals, closes the circuit of the voltage supply, and thereby is accompanied by a big current rush, which gives the brilliancy and the noise. If, however, the spark does not short-circuit the voltage, but the current is limited, as for instance by a very high resistance, or by the interposition of a dielectric in the discharge path, which does not puncture, as a glass plate, the apparent difference between Geissler tube glow and static spark is much less. Thus if we have a spark discharge between two terminals, with a glass plate interposed to keep the discharge from short-circuiting, with a considerable distance between the terminals, and correspondingly high voltage, we get static sparks jumping from the terminals to the glass plate, which are of the same character as the typical short-circuiting spark, but less brilliant and less noisy. Decreasing now the distance between the terminals, and the voltage, the sparks become more numerous, but still fainter and less noisy, and gradually change to so-called "steamers," which pass with a hissing noise in sharply defined faint lines, and finally, when still further shortening the gap, the noise disappears, and the discharge changes into a uniform and noiseless faint glow, very similar to that of the Geissler tube.

Thus we can pass gradually from the noisy and brilliant short-circuiting spark to the streamer, brush discharge, corona and to the silent discharge or steady glow.

But while a gradual transition from Geissler tube conduction to spark conduction exists, I have never been able to get any gradual transition from Geissler tube conduction to arc conduction, but under conditions where both can occur, the one always changes abruptly into the other, and these two classes of

conduction thus seem to be different in their nature: the one conduction by the gas in the space between the electrodes, the other conduction by a stream of electrode vapor. Both can be produced in the same tube, as a mercury arc and a striated Geissler tube discharge through mercury vapor, but the one cannot be changed into the other gradually, but the change always is abrupt. For instance, if we have a Geissler discharge through mercury vapor, of limited current and high voltage, and gradually cut the resistance or reactance out of the circuit, or increase the supply voltage, the Geissler discharge suddenly, with a "flash" changes to arc conduction; the current rises and the voltage drops. Cutting resistance in again, just as sudden the arc drops, and is superseded by the Geissler discharge.

Here then we have a very interesting and very important field, in the conduction of gases and vapors, in which still very much is unknown.

Magnetism has been the phenomenon of the greatest importance to the electrical engineer since the earliest days, since all electrodynamic machinery is based on the use of the magnetic field. Nevertheless, even in this field we have in "permanent magnetism" a phenomenon which is still unexplained, and mysterious. Permanent "magnetism" was a satisfactory expression once, but is not now, as "magnetism," "electricity," etc., are general terms now, without any definite and well defined meaning. So the question is, what is permanent in the permanent magnet? The magnetic flux, or the magnetomotive force, or the flux density or flux distribution, or the magnetic energy?

Another interesting and important phenomenon of magnetism is the loss of energy by a cyclic change of magnetism, as occurs in an alternating magnetic field. Twenty years ago, I found this loss to be expressed empirically by the 1.6th power of the magnetic flux density, with sufficient approximation over a wide range of magnetic densities. Since that time, some observers have found that for very high magnetic densities the loss is less than that given by this law of the 1.6th, and other observers found that it is more. Considering the great difficulty of getting exact results at high densities, it appears probable herefrom that even at high densities the law of the 1.6th power still applies at least approximately. For very low densities I have shown that it finally cannot continue to hold, but the coefficient

must increase to 2.0. However, with all the work done on magnetism, we still are entirely in the dark regarding the cause of this strange coefficient 1.6. The only other instance of such a fractional exponent is the exponent of the adiabatic expansion curve of gases, 1.4, etc.

Only recently another instance has been found, where the coefficient 1.6 appears.

The resistance of pure metals, as the tungsten filament, is proportional to the absolute temperature:

$$r = aT$$

The black-body radiation, however, is proportional to the 4th power of the absolute temperature, and if no other loss of power occurs, as when the radiator is enclosed in a high vacuum, as in the tungsten filament incandescent lamp, the power input equals the radiation power, and thus also is proportional to the 4th power of the absolute temperature:

$$p = bT^4$$

substituting:

$$r = \frac{e}{i} \text{ and } p = ei, \text{ gives:}$$

$$\frac{e}{i} = aT$$

$$ei = bT^4$$

eliminating T, gives:

$$e^3 = \frac{b}{a^4} i^3$$

or:

$$e = ci^{1.6}$$

That is, in a perfect metal, which gives black-body radiation, in a high vacuum at higher temperature the impressed voltage varies with the 1.6th power of the current.

This is the only other instance of a 1.6th power law, which I found. It may be a mere coincidence, but it is interesting to reflect, that here as well as in the hysteresis law, a conversion of electric energy into heat takes place.

It is not possible to discuss all the unexplored fields of electrical engineering, or all the vast regions of otherwise well explored fields, where very little is known; but even in fields where very much is known, there are numerous trails leading

into unexplored regions, which never have been explored. Magnetism, for instance, is one of the most explored branches of electrical science. It was known many years ago, that manganese has some curious magnetic properties: a few per cent. added to iron makes it practically non-magnetic. However, it is non-magnetic only in its virgin state, and by heat treatment it is brought into a magnetic state, where it has about the same characteristics as other steels. Here then you find a material which may be magnetic or unmagnetic. This trail was never followed up until a few years ago, when a strongly magnetic alloy of manganese, copper and aluminum was discovered. It seemed to overthrow all our conceptions on the nature of magnetism as an elementary property. Even then, however, most investigators followed the same trail, making various alloys of these three metals, and speculating on the cause of the magnetic property of the alloy of three unmagnetic metals, without following the trail further, to the study of other alloys of these metals. Such study shows, that copper and aluminum are immaterial for the magnetic property, but that manganese is essential, and is indeed a magnetic metal. Pure manganese has never been produced in the magnetic state, but numerous alloys of manganese, as those with antimony, tin, zinc, etc., are magnetic or may be brought to a magnetic state. Most interesting is the manganese-antimony alloy, as it can be produced much easier than the Heussler alloy of manganese, copper and aluminum: mixing coarsely powdered manganese and antimony, in the proportion for instance of 1:3, by moderate heating—in a test-tube over the bunsen burner—the mass becomes strongly magnetic, and can be used to show the lines of force of a magnet, just like iron filings. When I tried the magnetic properties of a collection of various alloys, which I had since a considerable number of years, I found quite a number of manganese alloys, which showed magnetic properties. Thus after all we do not have to change our conception of magnetizibility as a property of the element, but it merely means, that manganese—and possibly chromium—have to be added to the list of magnetic metals.

Oxygen also is magnetic, and now should be easily available, but I do not know that its magnetic characteristics have ever been investigated, except very roughly and qualitatively. While

it may not be of industrial importance, it certainly is of great scientific interest, as the only magnetic non-metal and non-conductor. We do not know its magnetization curve, whether magnetic saturation occurs, and what the saturation value is, whether there is a hysteresis loss, etc., whether and how far ozone shows the magnetic properties, etc.

There is in the literature since many years a curious oxide of chromium mentioned, which has strongly magnetic properties. It is formed by the reduction of chromylchlorid, within narrow temperature limits.

With manganese, a lower oxide of the metal seems to exist, which has much greater magnetic properties than any of the manganese alloys investigated, and even on the old and well-known magnetic oxide of iron, the only data which we have are investigations made twenty years ago, but which apparently have never been continued further.

You see, there is really no lack of unexplored phenomena in the realm of electrical science and engineering, far more than can be touched upon in the short available time. But the two vast fields, in which an increased knowledge is of immediate industrial importance, and in which indeed energetic investigating work is going on, are the study of the properties of materials beyond the elastic limit, and the study of transient phenomena resulting from the readjustment of the stored energy of systems.

Most investigations of physicists have dealt with the properties of materials below the elastic limit, where the processes are reversible. But of almost greater interest is the range beyond the elastic limit, where the action of forces is not reversible, where mechanically the materials are deformed, flow, where the steel is rolled into rails, the wire is drawn. So with the electrical forces, in the electrostatic field, irreversible phenomena occur at high voltage, in the corona: energy is stored into the dielectric field, but is not returned, but dissipated as heat, if the dielectric flux density reaches beyond the disruptive strength of the material, and in our modern high voltage transmission lines we have closely approached this limit. In the field of magnetism, the phenomena of hysteresis represent such an irreversible process. So also the ageing of many kinds of magnetic materials, etc.

The second important field of investigation is the study of the transients. Transients are the phenomena, by which stored energy adjusts itself to changed conditions of the system. Most of our electrical engineering theory deals with the steady flow of electric power, by direct or by alternating current. But accompanying the flow of electric power is a storage of electric energy in the magnetic and in the dielectric field of the conductor, and any change of the circuit conditions, any change of current and of voltage, thus usually involves a change of the stored magnetic and dielectric energy. Since a change of stored energy cannot occur instantly—as this would represent infinite power—a transition period thus must intervene after every change of circuit condition, that is, an electrical transient occurs. When the electric systems were small, these transients usually were of negligible energy; but with our modern huge systems, the stored energy is such, that the transients frequently may reach destructive powers, and therefore their study has become of great industrial importance.

DISCUSSION OF DR. STEINMETZ'S PAPER.

Mr. W. C. L. Eglin: I am sure we are all very much indebted to Dr. Steinmetz, and I am sure he will be very glad to have any discussion that his remarks may have suggested.

Mr. H. C. Snook: I would like to ask whether Dr. Steinmetz thinks there is enough data at present to formulate any satisfactory theory of what electricity really is?

Dr. Steinmetz: While we still speak of electricity, or of magnetism, these terms have really ceased to have a definite meaning of some concrete thing or phenomenon, but rather mean an entire class of energy phenomena. With our increasing knowledge, instead of speaking broadly—and vaguely—of electricity, we discuss electric power, electric energy, electric current, voltage, quantity, etc., so that it may be said, that there is no such thing as electricity, but there is electric energy, electric power, etc., and the term electricity is applied largely to an entire class of phenomena. We may ask, "What is electric energy?" and then would answer, that it is a form of energy, which can be transmitted through a conductor, around which conditions of magnetic and dielectric stress are produced.

Mr. Snook: Yes, but there are two kinds of electricity, or two kinds of energy.

Dr. Steinmetz: Some speculative physicists have developed a conception of two forms of electric quantity, negative and positive. Others have denied the existence of positive and recognize only an excess or a deficiency of negative electric quantity. However, in reality, there is no absolute nega-

tive or positive, but it is entirely relative. That is, a point which is positive against another point, may be negative against a third point. For instance, the negative terminal of the mercury arc rectifier is the positive terminal of the rectified circuit fed by it.

Question: I would like to ask Dr. Steinmetz what are the elementary properties in a thing, or phenomenon, that make it electrical?

Dr. Steinmetz: I would define a phenomenon as electrical, if it is accompanied by magnetic or electrostatic fields.

Question: The difficulty with that answer is, that the word "electrostatic" is used for the properties which constitute the phenomena in the electrical field.

Dr. Steinmetz: You might define the electrostatic or dielectric field as a condition of stress in space, which exerts mechanical forces on light bodies, and which is polarized, that is, the forces may be in one, or in the opposite direction, positive or negative.

Question: Since the discovery of radium, they have formulated an electronic theory of mineral matter; that is, the influences are supposed to be the same thing that passes through the Geissler tube. Now if matter is composed of electrons, and matter is a flow of electrons, where do we stand?

Dr. Steinmetz: This conception attempts to begin, where we engineers end, that is, to explain how and why the phenomena occur. As engineers we are interested only in the facts, that is, determine how things occur. For instance: that in the arc, a stream of moving electrode vapor is the conductor. The metaphysician then speculates, why this moving vapor stream conducts, whether electrons carry electric quantities across the gap, and what these electrons are, etc. For us, this is of secondary interest only, and rather dangerous, since it is largely speculative, and you cannot safely design apparatus or build bridges with speculations, but you must have engineering facts.

Dr. Hoadley: There is one thing that has always had a certain amount of interest for me, and that is this: Suppose we have two insulated conductors, charged to a different potential with negative charges; and suppose we have two other conductors with positive charges; suppose that the two negative conductors are permitted to come in, and the two positive conductors are permitted to go together; what is the direction of the charge which reduces them to the same potential in each case?

Dr. Steinmetz: I think your premises are wrong. You speak of two conductors charged to different potentials with negative charges. But there is no negative charge, but negative is a relative expression only, and means negative with regard to another conductor as reference point, for instance, to the ground. Thus if you speak of two conductors of different negative potentials, it must be stated, with regard to what third conductor they are negative. They may be negative for instance with regard to the ground, and the two positive conductors positive with regard to the ground. But then that conductor, which is least negative with regards to the ground, is positive with regard to the conductor which is more negative towards the

ground, and the conductor, which is less positive towards the ground, will be negative towards the conductor, which is more positive towards the ground. But with regard to each other, of each pair of conductors, one is negative with regards to the other, and the other positive with regard to the former. You may, for instance, consider an insulated circuit, energized by a direct current source. One of its terminals is positive, the other negative, with regard to the other. If now you connect the circuit to the positive terminal of a high voltage source, of which you ground the other terminal, the entire circuit will be positive towards the ground, but still the one circuit terminal is negative regarding to the other, and the current flows in the circuit exactly as before.

That is, positive and negative are relative terms only, but not absolute, in their electrical engineering meaning.

Question: Mr. Chairman: The theory of thunder-storms production would seem to indicate that it is advisable to use ordinary lightning rods for the protection of buildings and high exposed points of structures. Is that correct?

Dr. Steinmetz: It is, undoubtedly. The lightning rod is a great protection, and I would not like to be in an exposed place without such protection. But you must not expect that one rod on one end of the building will completely protect the other end a hundred or more feet away. There must be sufficient rods to extend their protective zone over the entire area; the apex of the roof, and other projecting edges, must be protected by connecting wires, etc. That is, like any other apparatus, the lightning rod protection must be installed intelligently and properly, to be effective. But the general principle is correct, only, it must be rationally applied.

Nitrates in the Atmosphere of the Southern Regions. A. MÜNTZ AND E. LAINÉ. (*Compt. rend.*, clii, 166.)—The first step was to determine the quantity of nitrates and nitrites in the rain water of these regions for comparison with the quantity in the water of other parts of the earth. The production of these nitrous compounds in the atmosphere was found to be due to the frequent electric storms of the inter-tropical regions; which is corroborated by the fact that these nitrous compounds are not found at high altitudes, in the zone above that in which the storms are produced. The quantity of nitric acid varied from 1 to 4 m.g. per litre of water, while the highest figure for Alsace 0.43 m.g. and for England 0.42 m.g. At Caracas, the mean content was 2.23 m.g.

Wireless Telegraphy in an Aeroplane. A SENOUGUE. (*Compt. rend.*, clii, 186.)—Maurice Farman using a coil with a 10 cm. spark and fed by the current of four accumulators, sent clearly perceptible signals for a distance of 12 kilometres. One pole was connected by steel wires to the metallic body of the aeroplane, while the other pole was connected to carefully isolated

antennæ, consisting of two copper wires, 50 M. long and 0.4 m.m. diameter, hanging parallel to each other behind the apparatus. During the flight these wires attained an almost horizontal position. The total weight of the apparatus was about 20 k.g. Farman did not carry a passenger, but was his own operator. The waves were received by a Ferrié electrolytic detector, connected to horizontal antennæ 200 M. long carried on posts 8 M. high.

Heat Conductivity of Powdered Substances. M. SMOLUCHOWSKI. (*Anz. Akad. Wiss.*, Series A. 129.)—The heat conductivity of the following substances was determined experimentally, quartz sand, zinc dust, iron powder, zinc powder, rice flour, lycopodium seeds, cupic oxide, lampblack and kieselguhr, with special attention to the nature and pressure of the gases filling the interstices between the grains of the powders. The results showed that the heat conductivity of the powdered solids is mainly determined by the nature and pressure of the gas filling the spaces, and is very small if the gas is completely removed.

Silicon Monosulphide. L. CAMBI. (*Chem. Zentr.*, ii, 1863.) Ferrosilicon containing 90 per cent. of silicon was mixed with two parts of powdered sulphur and an electric current of about 80 ampères passed through the mass. After cooling in a current of CO_2, the gray product was treated with water and then evaporated. The non-volatile residue consisted of iron sulphide and undecomposed ferrosilicon. The monosulphide, SiS, was obtained in two forms: a compact, black substance and a yellow powder. The former has a density of 1.853 at 15° C., and sublimes at 940° to 980° C. at 20 to 30 mm. pressure. The yellow monosulphide is always formed when the black modification is sublimed. It is much less stable than the black, rapidly absorbing moisture from the air, and evolving H_2S, and becomes white. It dissolves in alkalies with evolution of hydrogen.

Celtium, a New Element. G. URBAIN. (*Compt. rend.*, clii, 141.)—Mons. Urbain, in the last few years, has approximately isolated a new element, lutécium, from ytterbium, but failed to obtain it in a pure condition for want of sufficient material. To obtain more he treated the earths of gadolinite. In the fractionations by repeated crystallizations, he obtained a few drops of a mother liquor which refused to crystallize. Of course all kinds of impurities accumulate in the mother liquor, so this was treated to eliminate everything but the rare earths, and the purified, perfectly white earth obtained was then examined, spectral analysis revealed the presence of lutécium, a trace of neo-ytterbium, of scandium and negligable traces of calcium and magnesium. There were also very intense rays, which did not coincide with those of any known body. This new element he calls Celtium with the symbol Ct.

VANADIUM ALLOYS.*

BY

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THE element Vanadium, while very widely distributed, has only in the last few years been available in sufficient quantities for metallurgical purposes. It is apparently diffused through all primitive granites, and many sedimentary rocks and clays. Its presence has been discovered in many iron ores, and practically all the American magnetites and secondary iron ore deposits contain small amounts. It occurs in larger amounts in many lead ores as the mineral vanadinite, a chloro-vanadate of lead, and until recently this mineral was the principal source of vanadium salts. Vanadium is also found associated with copper, zinc, and uranium ores. In 1905 a very large deposit of a new vanadium mineral was discovered in the Andes of Peru, near Cerro de Pasco, by Don Antenor Rizo Patron. This mineral, known as Patronite after its discoverer, is a sulphide of vanadium containing about 20 per cent. vanadium, and free from the usually associated metals, lead, zinc and copper. This deposit is the source of the greater part of the vanadium used in producing vanadium alloys to-day.

The element was first discovered by Del Rio in 1801 in the brown lead ores of Zimapan, Mexico, and named by him Erythronium. It was denied a place as a new element and was pronounced a basic chromate by Collet-Descostil in 1805 after examination of the ore sent to the Academy of Sciences by Humboldt. Del Rio himself came to this same conclusion in 1822. Then in 1830 the Swedish chemist Sefstrom discovered a new element in some remarkably soft and ductile iron made from the Taberg iron ores, and named it Vanadium, after the Scandinavian diety Vanadis. Immediately following this discovery Wohler identified the new element Vanadium in the Zimapan ores as the Erythronium of Del Rio. From this date on scarcely a year has passed without a record of the discovery

* Presented at the Meeting of the Mining and Metallurgical Section held Thursday, March 23, 1911.

of some new mineral, ore or rock containing vanadium, and investigations of its salts. It was soon found to be widely distributed but almost universally in such small quantities that it was classed as a rare element, and sufficient amounts for extensive chemical investigations were hard to obtain.

In 1863 Lewis Thompson suggested that perhaps vanadium has the same effect on iron as nickel, as its discovery was made in an iron of remarkable ductility and softness, and he hoped that more thorough experiments with this important metal would be made. This suggestion, as may be supposed, hardly created even passing comment, as vanadium was still so rare a metal that its salts were counted among the greatest of chemical rarities.

In 1864 Edward Riley discovered vanadium while analyzing some pig-iron smelted from the oolitic Wiltshire ores. He found as high as 0.686 per cent. present and even suggested the utilization of this pig-iron as a source of vanadium compounds. Quite an opposite proposition to that of Thompson's.

During the years 1867 to 1870 Sir Henry Roscoe made his very exhaustive researches on vanadium and its chemical compounds, reducing vanadium for the first time to the metallic state. This metallic vanadium, however, as a matter of fact, contained about 3 per cent. of impurities. Owing to its great affinity for oxygen, nitrogen and carbon at high temperatures and its power of absorbing hydrogen, vanadium has not yet been separated in the pure state. Roscoe's source of supply was the lime precipitate obtained as a residue in extracting cobalt from a sandstone deposit at Mottram, Cheshire, England. While no analysis of the percentage of vanadium in this sand rock is known, the fact that the deposit contained only a few tenths of a per cent. of cobalt gives us an idea of how small a percentage must have been present. It is interesting to note that this deposit was for a time a leading source of supply of vanadium compounds.

Following closely Roscoe's researches came the first industrial application of vanadium, the use of its salts in the manufacture of aniline black. From this date on to 1900 practically the only applications of vanadium were in the manufacture of aniline black, indelible inks, dyeing and calico printing. It was used to some extent also in the ceramic industry on account of the fine gold colored glaze with greenish tinge to be obtained from

the oxides. The two principal sources of supply at this time were the Spanish lead mines and the basic steel slags from Le Creusot Steel Works, France. In 1882 it was discovered that these slags contained slightly over 1 per cent. vanadium, and as lately as 1902 there were produced yearly about 165,000 pounds of oxide from this source, all of which went into the aniline and dyeing industries.

About 1890 vanadium appears to have entered the domain of metallurgy and the production of metallic vanadium, and its alloys attempted with a view to industrial application.

Moissan in 1893 in the course of his researches in the reduction of refractory metals in the electric furnace, undertook the production of metallic vanadium. Owing to its great affinity for carbon his purest metal contained from 4.4 per cent. to 5.3 per cent. of carbon. To produce this he was obliged to have the carbon tube in which the reduction was made filled with hydrogen. According to Moissan, of all the refractory metals he was able to prepare in the electric furnace, vanadium was the most infusible. He discovered while investigating the carbides of vanadium, that notwithstanding its very high melting point, 1680° C., vanadium readily alloyed with iron, copper and aluminum. He produced a ferro-vanadium containing 20 per cent. vanadium and 8 per cent. carbon, and found that the carbon content of the alloy rapidly increased with the length of time it was in the furnace. By replacing iron oxide with copper oxide he produced an alloy of copper and vanadium containing 96.5 per cent. copper and 3.38 per cent. vanadium. This alloy was considerably harder than copper, but malleable and easily filed. By adding a mixture of vanadium oxide and powdered aluminum to a bath of melted aluminum, he produced an alloy with 2.5 per cent. vanadium, and suggested this method as a ready means of producing alloys of refractory metals. Subsequent investigations have shown that vanadium also alloys readily with manganese, nickel, chromium, silicon and other metals.

In the course of his investigations on the carbides of vanadium Moissan found that while there were several carbides CV, CV_2, C_3V_4, and C_2V_3, the one generally formed was CV, containing theoretically 18.97 per cent. carbon and 81.03 per cent. vanadium. He succeeded in producing some of this carbide containing 18.39 per cent. carbon and 81.26 per cent. vanadium.

In 1899 Cowper-Cowles succeeded in depositing metallic vanadium electrolytically, but I have seen no analysis of this metal, and no additional investigations along this line appear to have been made. Slight changes in current density, temperature and concentration of the electrolyte caused precipitation of the oxides instead of metal.

While there appears to be some evidence that the effect of vanadium when added to iron and steel was known to some extent in 1890, the more important investigations recorded are those on armor plate at Firminy in 1896, and a report on vanadium in steel, copper and aluminum alloys by Helouis before the Society for the Encouragement of National Industries, France, the same year. Practically nothing developed from these tests, principally no doubt on account of the high cost of the material and the limited supply in sight. In the case of the Firminy tests great difficulty was experienced in getting the vanadium into the steel, and in fact only one out of the three tests made proved successful. The results of this test, however, were quite conclusive in superiority.

It was not until the more complete and comprehensive investigations of Prof. Arnold in 1900 that vanadium began to receive the attention it deserved as an alloying metal. Arnold's tests were made both upon low carbon and high carbon steels. He found that a 1.25 per cent. carbon steel with 3 per cent. vanadium would cut 75 per cent. more turnings than the same steel with 3 per cent. of tungsten. In the case of the soft steels he found that the elastic limit was raised from 30 to 50 per cent., without impairing their ductility, by the addition of a few tenths of a per cent. of vanadium. He gave it as his opinion that vanadium is undoubtedly the element which together with carbon acts with the greatest intensity in the way of improving alloys of iron, that is to say, in very small percentages. This was just at the beginning of the high-speed tool-steel era, inaugurated by the exhibition of Taylor-White Steel at the Paris Exposition. One of the best of the Taylor-White steels was a chrome-tungsten steel containing 0.30 per cent. vanadium, and to-day practically all the leading brands of high-speed steel contain vanadium.

Following Arnold came the very complete work of Sankey and Smith on chrome-vanadium steels published before the Institute of Mechanical Engineers in 1904, and this might be said to

mark the beginning of vanadium steel as a commercial product. With the discovery in 1905 of the Peruvian deposit, a plentiful supply of vanadium was assured and its use in metallurgy became at once possible.

While vanadium alloys readily with quite a number of metals, by far the most important alloy is with iron, and its greatest application is in the manufacture of alloy steels. In 1905 there were produced about 800 tons of vanadium steel, most of which went into the automobile industry and high-speed tools. Last year I estimate that there were produced over 50,000 tons of vanadium steel, a record that is very creditable considering that there were during the interval three somewhat lean years in the steel industry.

The metal vanadium has an atomic weight of 51.3; specific gravity of 5.5; is non-magnetic; has a high electrical resistivity; melts at 1680° C.; is the most difficult to reduce and the hardest of the metallic elements. Owing to its very high melting point, vanadium, even if it were possible to produce it reasonably pure in the metallic state, would present very considerable difficulty in alloying with other metals. To overcome this difficulty and make it easier to introduce, special alloys rich in vanadium are produced.

Ferro-vanadium is approximately an alloy of two parts iron and one part vanadium, usually ranging from 30 per cent. to 40 per cent. vanadium. Aside from vanadium and iron, the alloy contains some silicon and aluminum, generally less than 2 per cent. of each. It has a melting point of about 1340° C. to 1400° C. The melting point of ferro-vanadium depends both upon the per cent. of vanadium contained and also upon the percentage of other metals present, such as silicon and aluminum. The specific gravity is 7.34. The alloy is hard, but not brittle, and is crushed with considerable difficulty. Armor plate and manganese steel jaw plates are worn out with considerable rapidity in the crushers.

In case the alloy is prepared by the electric furnace process, it will contain from 1.5 to 6 per cent. or more of carbon. This carbon is present in combination with vanadium in the proportion of about 4.25 per cent. vanadium for each per cent. of carbon. Carbide of vanadium will not alloy with iron, and on adding ferro-vanadium containing this to steel, the carbide is either all

lost by rising to the surface, or some of it may remain in the steel in mechanical suspension, giving rise to hard spots and otherwise impairing the physical qualities of the steel. On this account most of the ferro-vanadium is made by the well-known aluminum reduction process, which produces carbon-free alloys.

I have taken a ferro-vanadium containing 6 per cent. carbon and treated it in the finely powdered condition for a week with hydrochloric acid, drawing off and renewing the acid daily. The acid from each treatment was tested for vanadium, but no trace was found. By the end of the week all the iron had been apparently dissolved out of the sample, and the residue on analysis was found to contain practically nothing but carbon and vanadium, showing that in the case of this ferro-vanadium no vanadium had alloyed with the iron.

The vanadium is extracted from the ores by chemical means and converted into oxide for reduction. This oxide is mixed with iron oxide and powdered aluminum and the mixture reduced in large magnesite lined crucibles. The whole mix is not usually fired at once as in the case of the well-known Goldschmidt Thermit Process, but is generally fed into the crucible in small amounts. In this way the reaction is less violent, and under better control.

Vanadium is undoubtedly the most powerful metal yet discovered for alloying with steel. Its intensifying effect on the other elements in the steel, carbon, silicon, manganese, chromium, etc., is so great that although these elements are usually present in greater amounts, the steel is improved and changed to such a degree that it is designated as vanadium steel, chrome-vanadium steel, etc. To quote still further Professor Arnold's opinion of the effect of vanadium on steel: He was of the opinion that vanadium combined to form a double carbide of iron and vanadium, and it seemed to have not only a chemical, but a physical influence in promoting the even distribution of the carbon, and retarding constitutional segregation. From this and other experimental evidence there is the strongest reason to believe that very small percentages of vanadium will largely enable steel to resist that deterioration which under continued vibration leads to brittleness. This opinion of Professor Arnold has been entirely confirmed by the record of vanadium steels during the ten years that have since elapsed, and they have well earned the name of

"anti-fatigue" steel. Two to three-tenths of a per cent. of vanadium augments the properties produced by quenching, elastic limit, tensile strength and hardness, without sensibly modifying the ductility of the annealed steel.

In addition vanadium through its affinity for oxygen and

TABLE I.

BALLISTIC TEST SPECIFICATIONS FOR STANDARD NICKEL STEEL PROTECTIVE DECK PLATING.

Guage of plate, inches.	Caliber of gun, inches.	Striking velocity, foot-seconds.	Striking energy, foot-tons.	Angle of impact, degrees.
1	4	1912	110	7
1½	6	1775	275	7
2	6	1850	300	7
2½	6	1925	415	9
3	6	2000	450	9

TABLE II.

BALLISTIC TEST SPECIFICATIONS FOR CARNEGIE "SPECIAL TREATMENT" STEEL PROTECTIVE DECK PLATING.

Gauge of plate, inches.	Caliber of gun, inches.	Striking velocity, foot-seconds.	Striking energy, foot-tons.	Angle of impact, degrees.
1	6	1330	192	9
1½	6	1910	398	9
2	8	1540	650	9
2½	8	1870	960	9
3	8	2160	1270	9
3½	8	2410	1580	9
4	8	2640	1900	9

CARNEGIE "SPECIAL TREATMENT" STEEL APPROXIMATE PHYSICAL CHARACTERISTICS.

Ultimate Tensile Strength	130.000 lbs. per sq. inch.
Elastic Limit	118.000 lbs. per sq. inch.
Elongation in 2 inches	19 per cent.
Reduction of Area	50 per cent.

nitrogen acts as a scavenger in the manufacture of steel. On account of its price, however, it is not used primarily for this purpose, and the steel makers' aim is to sacrifice as little for this purpose as possible.

As we have already seen, one of the earliest applications of vanadium to steel considered was for war material, and some thin plates were actually tested out by the Firminy Steel Works in 1896. It is not surprising then that when an assured supply of vanadium at a reasonable price became available its applica-

TABLE III.

STANDARD NICKEL STEEL PROTECTIVE DECK PLATE NO. 262580-A (TWO INCHES THICK) TESTED AT INDIAN HEAD PROVING GROUNDS, FEBRUARY 19, 1907.

NORMAL IMPACT

	Round No. 1.	Round No. 2.	Round No. 3.
Gun	3-inch	3-inch	3-inch
Weight of projectile	13 lbs.	13 lbs.	13 lbs.
Striking velocity	1015 ft.-sec.	1065 ft.-sec.	1165 ft.-sec.
Penetration	Complete	Complete	Complete

TABLE IV.

CARNEGIE "SPECIAL TREATMENT" STEEL PROTECTIVE DECK PLATE NO. 333-E (TWO INCHES THICK) TESTED AT INDIAN HEAD PROVING GROUNDS, DECEMBER 28, 1907.

NORMAL IMPACT

	Round No. 1.	Round No. 2.	Round No. 3.
Gun	3-inch	3-inch	3-inch
Weight of projectile	13 lbs.	13 lbs.	13 lbs.
Striking velocity	1632 ft.-sec.	1889 ft.-sec.	2074 ft.-sec.
Penetration	$\frac{1}{16}$ inch	$\frac{5}{16}$ inch	$\frac{1}{4}$ inch

tion to steel for war material, especially armor plates, was promptly taken up. The combined properties of great hardness and toughness possessed by vanadium alloy steels being just what is necessary for armor plate, to-day all the protective deck plate, gun shields, and plate for splinter bulk heads are made of vanadium alloy steel. By the use of vanadium in these plates the

Government has been able to raise the specifications for ballistic tests very materially. Through the courtesy of the Carnegie Steel Company, I am able to show by means of tables and curves what these increased requirements are and how great the superiority of the vanadium steel plates are over those furnished under the old specifications. Tables I and II show comparative tests made on two protective deck plates, one of the standard nickel steel, and the other vanadium steel. In these tests the impact was normal, while in the regular test of such plates the impact is at a small angle. The size of gun and weight of projectile were the same for both plates, but the striking velocity was much greater for the vanadium plate. The penetration was complete for each round in the case of the nickel steel plate, while the greatest penetration of the vanadium steel plate was ¾ of an inch, by a shot with nearly 80 per cent. more striking velocity.

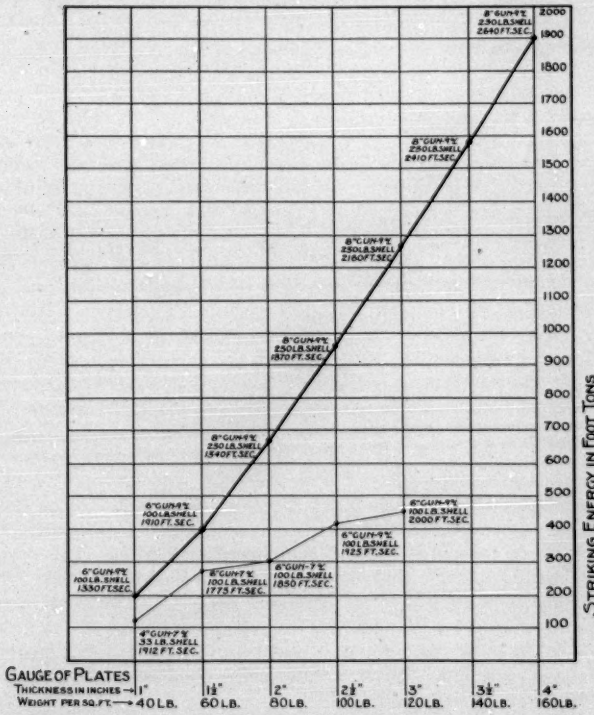
Tables III and IV give the old ballistic test specifications for nickel steel protective deck plates, and the new specifications for the vanadium steel plates. To pass test, the plates must not be penetrated, nor show any through cracks. The curve (Diagram I) shows graphically these requiremets and gives a very good idea of the tremendous superiority of the new plates over the old ones. The upper curve is the vanadium steel and the lower curve the nickel steel formerly used. The plates represented in each test passed specifications.

Tests now under way show that vanadium steels retain a much larger proportion of their hardness and strength at elevated temperatures than other steels. This has also been confirmed by the behavior of vanadium steels in service, notably in gas engine exhaust valves and high-speed tool steels. This property would indicate that vanadium steel is the best material to resist erosion of gun tubes and rifle barrels. The erosion of gun tubes by smokeless powder is a very serious matter, and one that is receiving very much consideration to-day. As a matter of fact, vanadium steel is already being used to a considerable extent for rifle barrels.

The vanadium alloy steels containing the highest percentage of this element are the so-called high-speed tool steels. These are medium carbon, chrome, tungsten steels containing from 0.5 to 1 per cent. of vanadium. The effect of the vanadium has been to

increase the efficiency of this steel about 30 per cent., due very probably in a great measure to the property mentioned just now of vanadium steels retaining a large proportion of their strength

DIAGRAM I.



and hardness at high temperatures. Practically all of the highest grade high-speed tool steels contain vanadium.

The vanadium alloy steels having the widest applications are what might be termed alloy machinery steels. These are chrome-vanadium, nickel-vanadium, and chrome-nickel-vanadium, and

were developed, one might almost say, to meet the especial requirements of the automobile industry. They found their first application in this industry, then in its infancy, rapdly finding out that ordinary machinery steel could not meet the requirements. The railroads also promptly began testing out vanadium steel for special parts, and are now extensive users of these steels. To-day vanadium steels have a very wide and rapidly increasing application. Like all other alloy steels, they should only be used in the heat-treated condition in order that the full extent of their superior qualities may be developed.

I would like to emphasize this matter of heat treatment. This is one of the most important operations to which steel is subjected; in a way it is the most important, as it is generally the final one. It is essential that the work be done by skilful men, supplied with accurate pyrometers and well designed and constructed furnaces capable of maintaining a uniform heat and of being easily regulated. The quenching tanks should be conveniently located and of suitable size for the work to be treated, and provisions should be made for maintaining the quenching medium at approximately a uniform temperature. Most essential of all, the man in charge of the heat treatment should know the composition of the steel and the temperatures best suited to bring out the desired properties.

The most important and widely used of these steels are the chrome-vanadium. These have been developed in three distinct grades or types, generally known as Types "A," "D," and "E," typical analyses being as follows:

	"A"	"D"	"E"
Carbon	0.25 per cent.	0.45 per cent.	0.15 per cent.
Manganese ...	0.45 per cent.	0.80 per cent.	0.30 per cent.
Chromium ...	0.80 per cent.	1.00 per cent.	0.30 per cent.
Vanadium ...	0.18 per cent.	0.18 per cent.	0.12 per cent.

In addition to these there are rapidly coming into extensive use low nickel-chrome steels, with a range of composition about as follows:

Carbon	0.25 to 0.45 per cent.
Manganese	0.50 to 0.70 per cent.
Nickel	1.00 to 1.50 per cent.
Chromium	0.60 to 0.80 per cent.
Vanadium	about 0.18 per cent.

These steels are free from the treacherous qualities of the high nickel-chrome steels, and are destined to replace them to a great extent.

Type "A" steel is essentially an oil-tempering forging steel, though it is much used for casehardening gears, and other parts where great strength of core is required. The forgings are usually heat-treated to give an elastic limit of 100,000 to 110,000 pounds per square inch, with a tensile strength of 120,000 to 130,000 pounds per square inch; an elongation in 2 inches of 18 per cent. to 20 per cent., and a reduction of area of about 60 per cent. Much higher elastic limits are regularly obtained for crank shafts, propeller shafts, etc., when desired. The influ-

FIG. 1.

ence of the size of the forging on the physical properties to be obtained by heat-treatment is, of course, very important, and tests of heat-treated bars of small diameter are frequently criticized as representing results unattainable in commercial forgings. However, these tests serve a very useful purpose as a means of comparing different steels under similar conditions and also as a guide in the heat treatment of forgings. For the medium size sections used in the automobile industry the high results are quite readily attainable. In the case of forgings of large section, such as car and locomotive driving axles, a considerable reduction from such figures naturally must be expected, but in the case of the vanadium steels this reduction is not so great as for steels without vanadium.

I will not attempt in this paper to go extensively into details of heat-treatment and tests of vanadium steels, but will show by means of a few illustrations some of the tests that have been made on commercial material. These tests will give an excellent idea of the remarkable toughness of this high-strength steel.

Fig. 1 is an automobile crank shaft that has been distorted by repeated blows of a 2500-pound steam-hammer without sign of fracture. An excellent 0.35 per cent. carbon steel shaft was subjected to like test but could not be distorted to the same extent without fracture, the force exerted to an equal number of blows being only one-fourth that required to distort the Type "A" vanadium steel shaft.

FIG. 2.

Vanadium steel automobile forgings, physical tests: elastic limit, 110,000; tensile strength, 130,000; elongation in 2 inches, 20 per cent.; reduction of area, 57 per cent.

Fig. 2 shows a group of distorted automobile forgings, including an axle, connecting rod, transmission shaft, etc.

Fig. 3 is a locomotive side rod that was doubled over on itself by means of a falling weight of 4000 pounds used to break up scrap.

FIG. 3.

Vanadium steel side rod, physical properties: elastic limit, 101,000; tensile strength 125,000; elongation in 2 inches, 20 per cent.; reduction of area, 55 per cent.

Fig. 4 is a locomotive piston rod, both ends of which have been machined down for test as shown. One end was tested by giving it one complete twist, the other was pulled in the test machine until just about ready to break—the results given are from this test.

Fig. 5 is a locomotive driving axle, 9½ inches in diameter, bent through 180 degrees without fracture. A carbon steel

axle with the same elastic limit would not stand bending over about 7 to 10 degrees. The average tests of 185 driving axles was:

Elastic limit	82,480 pounds per square inch.
Ultimate strength	109,540 pounds per square inch.
Elongation in 2 inches	21.3 per cent.
Reduction of area	57.3 per cent.

Elastic limits of 120,000 pounds per square inch with 15 per cent. elongation in 2 inches and over 40 per cent. reduction of area can be obtained in these driving axles if desired.

It is well to know that for the past six or seven years the railroads and the Government have been jointly investigating the problem of safe transportation of explosives. Classed among the explosives are the commonplace seamless cylinders of compressed

FIG. 4.

Vanadium steel piston rod, physical properties—actual test: elastic limit, 101,650; tensile strength, 124,875; elongation in 2 inches, 21.50 per cent.; reduction of area, 37.16 per cent., and not broken.

carbonic acid gas, oxygen and other gases. These not infrequently burst through overcharging, increased pressure due to exposure to heat, etc. The great danger lies in the flying pieces of the cylinders when they burst. It is very desirable that these cylinders be made from a strong steel that will not shatter upon bursting. At the same time lightness of cylinder is very desirable from a commercial stand-point. Low carbon steel, annealed, will not shatter, but in order to obtain the requisite strength to withstand the gas pressure safely, the cylinders become too heavy.

About eighteen months ago the National Tube Company made a very extensive series of comparative tests to determine if it were possible with any steel to meet all the requirements; freedom from shattering, strength and lightness. Through the courtesy of this company I am able to show you photographs of tested cylinders from several of these series of tests. The low carbon cylinders shown in Fig. 6 are standard cylinders used for

oxygen, 7⅝ inches outside diameter, 43 inches long, walls ⅜ inch thick and weigh 108½ pounds on an average. They have

FIG. 5.

Vanadium steel locomotive driving axle, 9¾ in. diameter, bent cold under 14,000 ton press: elastic limit, 75,000 pounds; tensile strength, 100,000 pounds; elongation in 2 inches, 20 per cent.; reduction in area, 50 per cent.

FIG. 6.

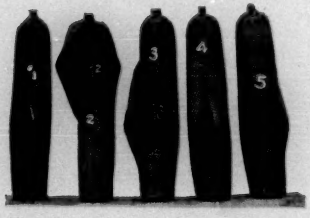
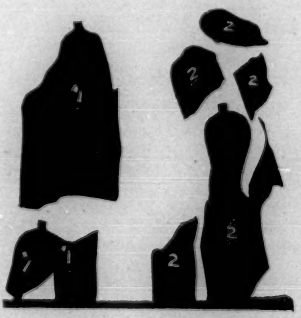


FIG. 7.



an average yielding pressure of 3600 pounds per square inch and a bursting pressure of from 6600 to 7000 pounds per square inch.

Fig. 7 shows annealed high carbon (0.41 per cent.) cylinders frequently used for carbonic acid gas. These cylinders are larger and lighter than the low carbon ones. The dimensions are 8½ inches outside diameter, 51 inches long, wall ¼ inch thick, and average 94½ pounds in weight. The average yielding pressure was 3000 pounds per square inch and the bursting pressure from 5000 to 5900 pounds per square inch.

Fig. 8 shows annealed high-silicon (1 per cent.) steel cylinders of the same size and weight as the high carbon cylinders. These had an average yielding pressure of 3800 pounds per square inch, and a bursting pressure of from 5000 to 5950 pounds per square inch.

Fig. 9 shows chrome-vanadium steel cylinders of the same length and thickness of walls, but $^{3}/_{16}$ inch larger in diameter,

FIG. 8.

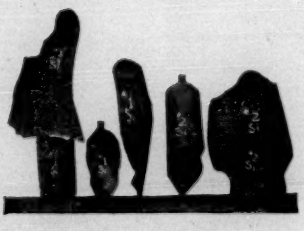
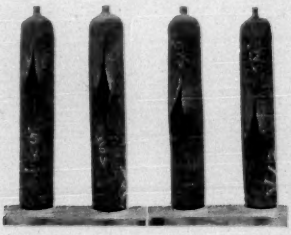


FIG. 9.

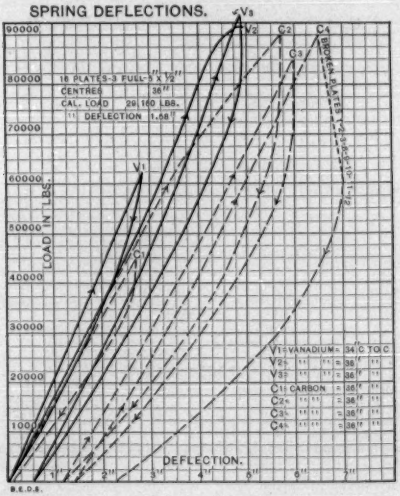


and had an average weight of 105 pounds. These cylinders were all double treated, that is, quenched and then annealed or drawn back. The yield pressure for the cylinders shown ranged from 6200 to 8200 pounds per square inch, and the bursting pressure from 6450 to 8500 pounds per square inch. As a result of these tests, the Government is now specifying chrome-vanadium steel seamless air-flasks for all naval purposes, and doubtless gas cylinders will eventually be made of this material in order to meet future transportation requirements.

Type "D" chrome-vanadium steel is used principally for springs, oil-tempered gears and pinions. It is also used in the mild or lower carbon grades for automobile rear axle shafts, crank shafts, and other parts where a high elastic limit is desired.

The higher drawback temperature at which the same elastic limit can be obtained makes it preferable to the Type "A" steel under some conditions. The high elastic limit coupled with great tough-

FIG. 10.



COMPARATIVE TESTS ON VANADIUM AND CARBON STEEL SPRINGS.

TESTED BY THE AMERICAN LOCOMOTIVE COMPANY.

THE VANADIUM SPRING WAS TESTED:

1. To 62,700 lbs. with 34 inch centres.
2. To 92,000 lbs. with 36 inch centres.
3. To 94,000 lbs. with 36 inch centres.

On second test, elastic limit was reached at 85,000 lbs. or 234,500 lbs. fibre stress with permanent set of 0.48 inches.

The third test was repeated three times without the least variation from recorded heights.

THE CARBON SPRING WAS TESTED:

1. To 44,000 lbs. with 36 inch centres.
2. To 89,280 lbs. with 36 inch centres.
3. To 84,520 lbs. with 36 inch centres.
4. To 89,280 lbs. with 36 inch centres.

On second test, elastic limit was reached at 65,000 lbs. or 180,000 lbs. fibre stress with permanent set of 1.12 inches.

On third test, it took an additional set of 0.26 inches and on fourth test, plates 1-2-3-8-9-10-11-12 failed at the centre.

STATIC TEST ON PIECE CUT FROM LEAF OF SPRING.

Elastic limit, 227,100; ultimate strength, 237,500; ratio, 96 per cent.; elongation 2 inches, 10 per cent.; contraction of area, 35 per cent.

TYPE "D" VANADIUM SPRING STEEL.

ness, and the more rapid recovery of vanadium steels from over-strain makes Type "D" the ideal steel for springs.

Fig. 10 shows a comparative test of two locomotive springs,

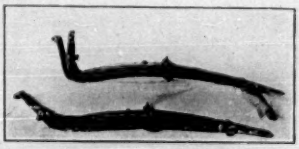
one from standard carbon spring steel, the other from Type " D " vanadium steel.

Fig. 11 illustrates very well the remarkable toughness of vanadium steel. These springs were taken from wrecked automobiles.

Fig. 12 shows very clearly the importance of heat-treatment. These two fractures are from the same plate of steel from a defective semi-elliptic spring. The coarse fracture shows the original condition of the steel in the spring, and readily accounts for the failure; the other fracture shows the steel as it should have been.

Type " D " chrome-vanadium steel is showing up remarkably well in locomotive tires and solid-rolled-steel wheels, and there

FIG. 11.



Vanadium steel springs: bent in an automobile wreck.

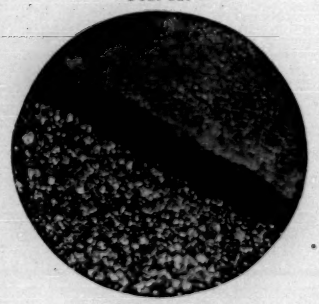
is already some demand for vanadium tires and wheels for severe service.

An interesting example of the application of Type " D " steel is for hot and cold saws in steel mills. A hot saw running 1100 r.p.m., 17300 feet per minute, cutting 15-inch to 24-inch I-beams, made a record of 1800 tons with one dressing. The average for carbon steel saws was 125 tons. Another saw cutting slabs 5 inches thick by 30 inches wide made 585 cuts. The average for the carbon steel saws was 9 cuts. A high-speed disc cold saw cut 1890 gross tons, equivalent to the work of 70 standard saws.

Type " E " steel is essentially a casehardening steel, and is used extensively for clash gears. It is also an excellent steel in its normal condition for bolts, rivets, and plates for pressed frames. Casehardened, it gives a strong, tough, hard, and closely coherent case, with a strong ductile core. These points are well shown in Fig. 13.

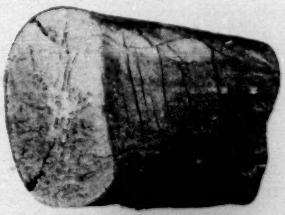
The use of vanadium in steel is not confined to what are known as the alloy steels. A very large tonnage of steel castings is being made to-day containing vanadium. One of the early applications of vanadium was in cast steel frames for locomotives. For this purpose vanadium steel has made an enviable reputation, as out of some 1500 frames there have been less than six known failures. Some of these frames have been put under engines that have had bad records as frame breakers. The elastic limit of vanadium steel castings averages about 30 per cent. to 40 per cent. greater than for plain carbon castings of the same

FIG. 12.



Diam. 13.

FIG. 13.



Casehardened vanadium steel. This steel was casehardened in the perfect round section, and after quenching, was beaten out cold to the shape shown, under a heavy power hammer.

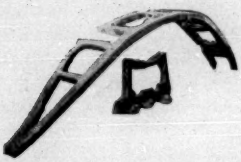
composition. The dynamic strength is from 50 per cent. to 75 per cent. greater. Vanadium cast steel is also being used to a considerable extent for rolling mill pinions and is giving from two to three times the life of ordinary carbon cast steel pinions.

Fig. 14 shows a locomotive frame tested by a falling weight; and Fig. 15 a rolling mill pinion after having outworn a 3½ per cent. nickel steel pinion. This pinion has since outworn a second nickel steel pinion.

There are many vanadium steel castings made by the crucible process, and Fig. 16 illustrates the remarkable toughness combined with high strength that is being obtained through the addition of about ¼ per cent. of vanadium.

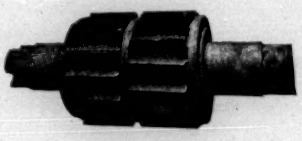
While vanadium alloys readily with nickel, chromium, manganese, silicon, copper, aluminum and some other metals, only the alloys of the last two mentioned apparently have any indus-

FIG. 14.



Vanadium steel engine frame section. Subjected to 20 blows from a 5000 lb. ball or trip dropping from a height of 18 ft. in the clear; supports four feet apart. Regular steel frame section invariably breaks on either the first or second blow.

FIG. 15.



Vanadium steel mill pinion, 46 inch diameter. A 3½ per cent. nickel-steel pinion, made by the same firm to the same pattern, and placed in companion service in the same rolling mill, was worn out completely, while the vanadium steel pinion continued in service and presented this appearance after rolling 100 per cent. more tonnage than the nickel-steel pinion.

trial application. It is possible that ferro-vanadium containing high percentages of chromium, manganese, or silicon might be of some advantage in steel making by reducing the amount of

FIG. 16.

Vanadium crucible steel casting cylinder for torpedo. Physical test: elastic limit, 65,000 pounds; tensile strength, 80,000 pounds; elongation in 2 inches, 22 per cent.; reduction in area, 43 per cent.

FIG. 17.

Diameter 210.

these metals to be added in the form of other alloys, but as yet there has been no demand for such special alloys.

Cupro-vanadium usually contains about 3 per cent. of vana-

dium. The eutectic alloy contains about 7 per cent. vanadium. Mixtures containing a high percentage are not desirable on account of the very high melting point and consequent difficulty in getting it into the alloys.

Vanadium has as yet hardly entered the field of non-ferrous alloys, although I firmly believe that in the near future it will be found occupying almost as prominent a place in these alloys as it does at present in steel. The principal reason for this apparent lack of progress has been due largely to the difficulty of producing cupro-vanadium free from undesirable metals, notably iron and aluminum.

Vanadium has a very high electrical resistance, and the addition of only a few hundredths of a per cent. reduces the conductivity of copper in a very marked degree. A few hundredths of a per cent. will increase the elastic limit, tensile strength and ductility of copper from 10 per cent. to 20 per cent.

About the first reference to the use of vanadium in non-ferrous alloys is contained in the article previously referred to by Helouis. He produced some experimental bronzes, notably an aluminum bronze, 94.5 per cent. copper and 5.5 per cent. aluminum with 0.5 per cent. vanadium, which gave a tensile strength of 97,336 as against 49,770 pounds per square inch for the same alloy without vanadium.

Vanadium has a very similar effect on the copper alloys that it has on steel. It increases both the elastic limit and tensile strength very materially and does not impair the ductility. Usually the ductility is increased. A recent test of vanadium in a common brass or Muntz metal, 60 per cent. copper, 40 per cent. zinc, gave the following results:

	WITHOUT VANADIUM.	WITH VANADIUM (TRACE ONLY).
Ultimate strength	38,000 pounds	49,000 pounds
Elongation in 2 inches.....	28 per cent.	45 per cent.
Reduction of area.....	30 per cent.	42 per cent.

The increase in resiliency by tests on notched bars was a little over 80 per cent.

Tests of vanadium in manganese bronze gave the following results:

TESTS.

	MANGANESE BRONZE.	MANGANESE-VANADIUM BRONZE.
Elastic limit	30,560 pounds	50,560 pounds
Ultimate strength	54,160 pounds	81,440 pounds
Elongation in 2 inches	22 per cent.	12 per cent.
Reduction of area	18 per cent.	14 per cent.

COMPOSITION.

	MANGANESE BRONZE.	MANGANESE-VANADIUM BRONZE.
Copper	58.81 per cent.	58.56 per cent.
Zinc	38.08 per cent.	38.54 per cent.
Aluminum	1.22 per cent.	1.48 per cent.
Manganese	0.69 per cent.	0.48 per cent.
Iron	0.84 per cent.	1.00 per cent.
Vanadium	——	0.03 per cent.

The micro-structure of these bronzes also shows a very marked difference. Fig. 17 is the bronze without vanadium and Fig. 18 the one with vanadium. Magnification, 210 diameters in each case.

A very considerable amount of vanadium bronze is being made of a composition similar to manganese bronze, without manganese. This bronze is very strong, forges readily and resists corrosion to a very high degree. It is being used extensively for marine work, especially in torpedo and submarine boats. The torpedo tubes, Fig. 19, are made entirely of this metal, and parts such as exhaust headers, valves, and air cylinders to withstand heavy pressures. A cylinder 3 inches in diameter, 15 inches long, and walls $^{9}/_{16}$ inch thick has stood up under 9000 pounds water pressure. Tests of this bronze both cast and cold drawn into rods and wire are as follows:

	CAST.	COLD DRAWN ⅝ IN. ROD.	COLD DRAWN ⅜ IN. WIRE.
Elastic limit	28,500 pounds	80,000 pounds	81,500 pounds
Ultimate strength	71,000 pounds	92,000 pounds	100,700 pounds
Elongation in 2 inches	32.0 per cent.	11.5 per cent.	12.0 per cent.
Reduction of area	27.8 per cent.	29.3 per cent.	33.6 per cent.

Fig. 20 shows the micro-structure of the cast bronze, magnification 210 diameters.

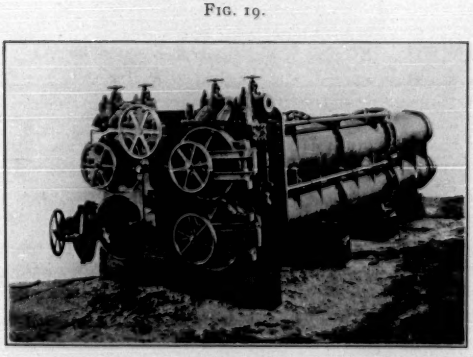
The possibilities of vanadium in bearing metals, both bronze

and babbitt I believe to be great. Work along this line has made little progress largely owing to the fact that the vanadium alloys at present available contain aluminum, and this element and lead

FIG. 18.

Diameter 210.

FIG. 19.



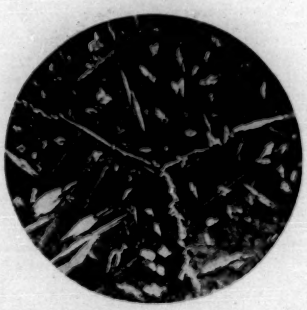
Torpedo tubes made entirely of Victor vanadium bronze.

are quite antagonistic towards each other. I have a report of a large, circular step-bearing in a plate-glass grinding machine that encourages me in my belief, that vanadium will improve the quality of the bearing alloys. These bearings are subject to

a load of 900 to 1000 pounds per square inch and make about 30 r.p.m. It has always been difficult to get a bearing metal hard enough to stand this pressure. This vanadium bearing metal was practically the standard American car journal bronze with approximately 0.05 per cent. vanadium added, and the bearing stood up twelve months with no appreciable wear.

Aluminum and vanadium readily alloy as was discovered by Moissan in 1896. Moissan's alloy contained 2.5 per cent. of vanadium, was stronger and a little harder than pure aluminum. Helouis in the article previously referred to made mention of an alloy of aluminum and 1 per cent. of vanadium which had a

FIG. 20.



tensile strength of 24,174 pounds per square inch. He also called attention to the remarkable sonority of these alloys. Matignon and Mounet produced an alloy of definite atomic composition, AV, containing 32.81 per cent. aluminum and 67.87 per cent. vanadium. The principal application of almino-vanadium will be as a means of introducing vanadium into aluminum and aluminum alloy castings, wire, sheets, etc., and consequently a low melting alloy will be required. The melting point rises of course with the percentage of vanadium. Recent experiments indicate that an alloy of from 5 per cent. to 10 per cent. of vanadium will prove most satisfactory. There is every indication that the use of vanadium in aluminum alloy castings will very considerably increase the strength and ductility.

THE HANDLING, TRANSPORTATION, AND STORAGE OF PERISHABLE FOODSTUFFS.*

A Review of the Work of the Food Research Laboratory, Bureau of Chemistry, U. S. Department of Agriculture.

(Contribution from the Food Research Laboratory, Bureau of Chemistry, U. S. Department of Agriculture.)

BY

JOSEPH SAMUEL HEPBURN, A.M., M.S.

PART I.

The Function and Equipment of the Laboratory and a Resume of the Researches Carried Out Therein.

INTRODUCTION 585—THE GENERAL ANALYSIS 587—PROTEIN ANALYSIS 588—FAT ANALYSIS 590—NEW METHODS OF ANALYSIS 591—PHYSICAL APPARATUS 592—BACTERIOLOGICAL WORK 594—HISTOLOGICAL STUDIES 597—ZYMOCHEMICAL INVESTIGATIONS 598.

During the year 1904–05 there was considerable agitation in the public press on the subject of foodstuffs, especially poultry and eggs, kept in what is commonly termed "cold storage," an elastic phrase in the popular mind and one which is commonly used to account for almost any undesirable condition observed by the consumer when buying perishable produce. So atonishing were the statements made by both the opponents and the advocates of "cold storage" that it seemed advisable for the Federal Government to make an impartial study of the question, that the consumer might not be injured by deleterious products on the market, and that the industries depending upon artificial refrigeration might be upheld if found worthy.

Accordingly the nucleus of the Food Research Laboratory, Bureau of Chemistry, U. S. Department of Agriculture, was established.

In the beginning it consisted of a single worker in a single room, and a part, only of that worker's time was given to the subject. Realizing that the chemical and bacteriological problems involved must be traced simultaneously, and that the funda-

* Presented at the Stated Meeting of the Institute held Wednesday, May 17th, 1911.

mental principles governing chemical changes and bacterial growth at low temperatures must be studied first in a medium which could lend itself to such investigation, the one worker in the one small room selected milk as the starting point. The fact that chemical changes did not cease, even when the temperature of the milk was below its freezing point, and that bacterial life was not extinguished—though both these processes were greatly slowed, was recorded in the paper published in 1908 in the *Journal of Biological Chemistry*.

Before the actual publication of this pioneer work, however, the study of poultry kept hard frozen for prolonged periods was begun. Cold storage warehouses, through the American Warehousemen's Association, were put at the disposal of the Department and all their facilities offered for the acquisition of knowledge concerning the changes in foodstuffs while hard frozen. At first the products found in the warehouses, and of which only a warehouse history could be obtained were examined. Such work, while giving information regarding the existing condition, furnished no way of determining previous treatment, nor did it tell what changes actually occurred during the freezing period, as differentiated from the fore period.

Therefore, it was necessary to prepare and freeze samples so that every detail of the preparation for storage should be known.

The analytical results from these birds of known history gave indispensable information, but still they were not adequate to cause a betterment of the industry and an improvement in the consumer's food supply. To accomplish this the laboratory—for by this time the staff had increased to chemists, bacteriologists, histologists, an artist, a stenographer and helpers, and appropriate laboratory quarters had been supplied—obtained the co-operation of every department of the poultry handling industry of the country, including packers, carriers, warehousemen, commission men and retailers. Every assistance and courtesy possible has been extended to the laboratory in this investigation. Every facility and all the trade knowledge possessed by the industry has been at our disposal. A realization that such a study on the part of the Federal Government meant incalculable advantage to the handlers of poultry and eggs, and ultimately to the handlers of all perishable products, has produced an

enthusiasm in bettering conditions and a keenness in seeking and applying advantageous knowledge that is almost phenomenal in any industry, and especially striking in such a scattered unorganized army as that which forms the poultry industry.

Along these broad lines the research work of this laboratory is now progressing. We are studying, with every assistance that modern science can give problems which are eminently practical and which mean betterment to both producer and consumer. The modus operandi by which we are seeking to attain these ends is set forth in the following pages.

In the course of these researches, old methods of analysis have been modified; new methods have been devised which are rapid yet very delicate; and the methods and machinery of physical chemistry have frequently been utilized. Since a change in chemical composition is closely related to an alteration of the physical structure, histological examinations of tissue have been carried out. Moreover, certain chemical decompositions are due to the action of lower organisms—bacteria, moulds and yeasts—hence the study of the number and species of bacteria in flesh have formed a large part of the work. Tissue enzymes play a rôle in the natural changes in foodstuffs, therefore, investigations in the field of zymochemistry have been undertaken. In this way the sample may simultaneously become the subject of chemical, histological and bacteriological examination, and may also be tested for various enzymes.

These studies have been carried out on chickens, eggs and milk. It is the purpose of this paper to describe the laboratory and its equipment, to review the researches carried out therein, and to give a resumé of the results obtained.

The chemical analysis of an animal foodstuff falls into two parts, the study of the fat, and the study of the flesh; the latter is subdivided into the general analysis and the separation and determination of the various proteins.

THE GENERAL ANALYSIS.

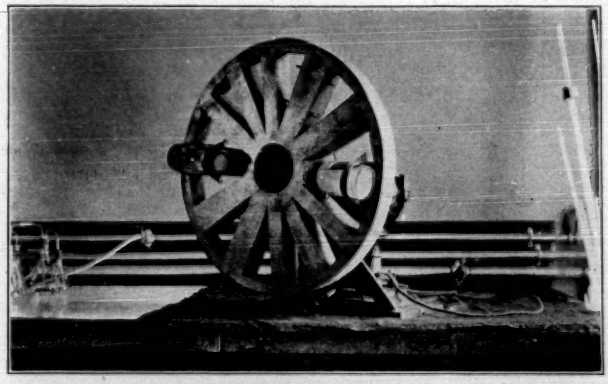
The general analysis consists of the determination of the total solids, water, fat, ash, protein and creatin. It serves as a check on the detailed analysis of the flesh, for the sum of the percentages of water, fat, ash and the two forms of nitrogen (protein and amino acid or creatin) should be approximately

100. Moreover the general analysis will reveal certain gross changes in chemical composition, for instance, during storage in the frozen condition the amount of water in the flesh of chickens decreases with a consequent rise in the total solids.

PROTEIN ANALYSIS.

In the detailed analysis of flesh from the food view point it is customary to determine the total content of nitrogen, the total nitrogen of the aqueous extract and each of the constituents of

FIG. 1.

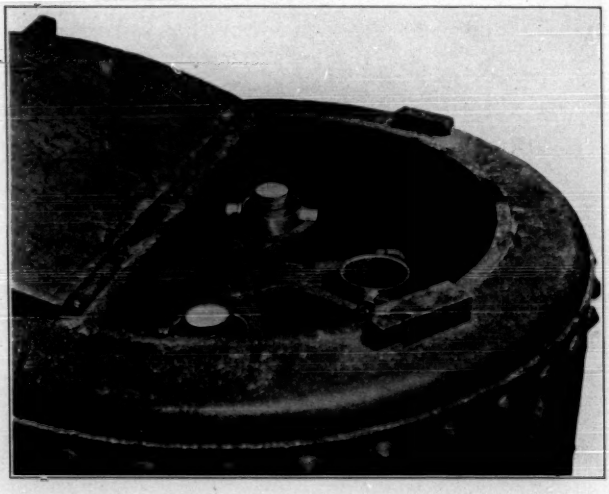


Shaking machine with bottles attached. Broad rubber bands are attached to the hooks on the side of the spokes, and pass over the bottles, which are thus held firmly in place upon the front of the wheel. The bottles are of 250 c.c. capacity and are provided with rubber stoppers. The contents are in two layers, the lower is the meat, the upper the aqueous extract.

that extract, *i.e.*, the nitrogen present in the form of coaguable protein, as albumoses, peptones, and amino acids. In the preparation of the aqueous extract of chicken flesh certain difficulties arose which were overcome by the use of a shaking machine and a centrifuge built especially for the purpose. The shaking machine is an upright wheel driven by a motor. The bottles containing meat and water are fastened to the spokes of the wheel, which is then revolved at such a speed that the contents of the bottles are gently agitated; the soluble constituents of the

flesh dissolve, but the motion is so gentle that no emulsion is formed. In order to collect the insoluble portion of the meat into a compact mass, and thus insure rapid filtration of the extract, the bottles are transferred to the centrifuge, which is able to carry a load of a litre at a speed of 3000 revolutions per minute. The supernatant liquid is removed by filtration,

FIG. 2.



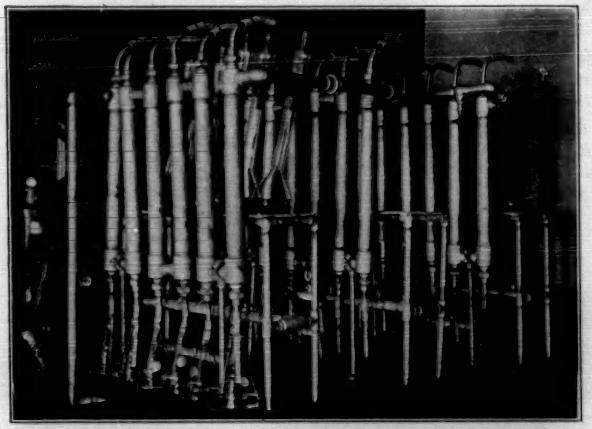
Centrifuge—equipped for chemical work. On the right is shown an empty carrier. The front and back carriers are loaded with rubber-stoppered, glass bottles of 250 c.c. capacity, such as were shown on the shaking machine. These bottles, which contain the meat and its aqueous extract, exactly fit the carrier. The fourth carrier is beneath the lid on the left and is not visible.

and extraction of the insoluble residue is repeated until all the soluble nitrogen has passed into solution. The combined filtrates are used for the analysis.

The study of the distribution of the nitrogen has shown that, during prolonged freezing, the protein of chickens undergoes a slow and specialized proteolysis; the digestion is similar to that produced by the action of the enzyme trypsin, as is shown

by the increase in the quantity of amino acid nitrogen; for instance, the light meat of fresh chickens on the average contains 8.44 per cent. of its total nitrogen in the form of amino acids;

FIG. 3.



Still for the determination of nitrogen as ammonia. The still is composed of three rows, each of which contains six upright condensers. The cooling water enters at the valve shown in the upper left hand corner, passes through the entire eighteen condensers and empties into the sink at the lower right corner. Each condenser consists of an outer iron jacket, and an inner tube of block tin, to the lower end of which a glass tube of the same diameter is attached by means of rubber tubing. Upon the front row, a distillation has just been carried out. The long-necked, pear-shaped, Kjeldahl flasks, which are used for both digestion and distillation, are connected to the inner tube of the condenser by means of rubber stoppers and safety splash traps (or distilling heads). The joint between trap and tube is made tight by means of rubber tubing. The distillate is caught in Erlenmeyer flasks. Heat for the distillation is supplied by gas burners.

after storage in the frozen state for 4 months, this form of nitrogen has increased and its mean quantity now amounts to 8.95 per cent. of the total nitrogen of the light meat.

FAT ANALYSIS.

In the analysis of the fat, not only have the ordinary constants like iodine, saponification and Hehner numbers and acid value been studied, but the investigation has also included within its scope at times such determinations as phosphorus content,

lactones, aldehydes, acetyl value, etc. Of the interesting changes which occur in the fat of chickens during their transportation and storage, the following examples may be given. If the birds be kept at either ordinary or lower temperatures, the acidity of the fat increases. The mean acid value of the fat of 6 fresh chickens was 0.8, while the mean value of this constant had risen to 2.5 in the fat of twelve birds which had been kept hard frozen for four months.

During storage in the frozen condition the saponification number and Hehner number undergo a change in the same direction at the same time; thus the fat of six fresh chickens gave a mean saponification number 173.5 and a mean Hehner number 82.10, while the fat of twelve chickens of known history hard frozen for four months had a mean saponification number 146.9 and a mean Hehner number 66.27; in other words both constants have undergone a simultaneous decrease. An extensive survey of the literature upon the natural changes occurring in fats and oils has failed to reveal any record of fat decomposition of this type, for an increase in saponification number is usually accompanied by a decrease in Hehner number and vice versa. Hence during the study of the changes in chicken fat *in situ* at temperatures below freezing a new type of fat decomposition has been observed.

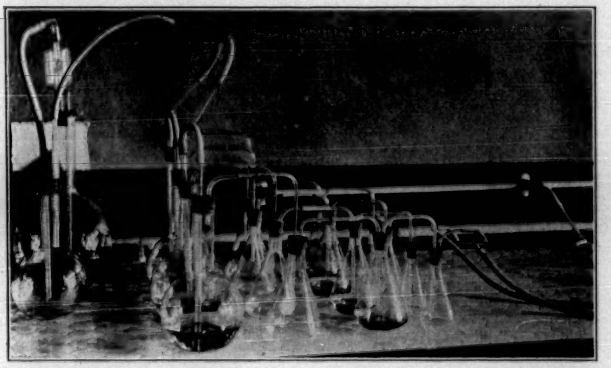
NEW METHODS OF ANALYSIS.

The extraction and analysis of fat consumes several days, as does also a complete protein analysis. Therefore in the study of the changes in fat and protein during the transportation and marketing of poultry, it became necessary to devise rapid yet very delicate methods of analysis, in order that several samples might be examined daily. The acidity of the crude fat was found to be an excellent indication of the amount of decomposition in the fat, and the quantity of ammoniacal nitrogen in the flesh was a delicate and accurate measure of the decomposition of the proteins. The crude abdominal fat is ground in a meat chopper; a sample is weighed out in a tared flask and heated on an electric stove with neutral alcohol until the latter boils briskly; the free acids are immediately titrated with standard alkali.

The determination of the ammoniacal nitrogen is based upon the following principles. If meat, magnesium oxide and water

be mixed at room temperature, the ammonia-like compounds will be liberated. If a current of air be drawn through the mixture, then through a known volume of standard acid, these volatile ammonia-like compounds will be removed by the air from the mixture and carried into the acid, which combines with and

FIG. 4.



Determination of ammoniacal nitrogen by aeration. The air is drawn through sulphuric acid in the large flask, passes through an empty flask which serves as a trap, then divides and is drawn through the flasks of which four sets are connected in parallel. In each set there is a generation flask, in which the ammoniacal nitrogen is liberated, then an empty flask which serves as a trap, next a flask containing a known volume of standard acid to absorb the ammonia-like compounds, and lastly another empty flask functioning as a trap. The latter is connected with the vacuum pump by rubber hose and iron pipe.

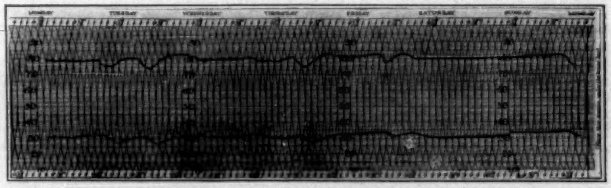
neutralizes them. At the end of the analysis, the excess of acid is determined and the quantity of ammoniacal nitrogen is calculated. The air current is generated by a vacuum pump driven by an electric motor.

PHYSICAL APPARATUS.

The methods and machinery of physics and physical chemistry find frequent application in the work of this laboratory. The microscope is an indispensable portion of the equipment of the bacteriological and histological laboratory. A special condenser for dark ground illumination produces total reflection at the upper surface of the coverglass of all the light rays save

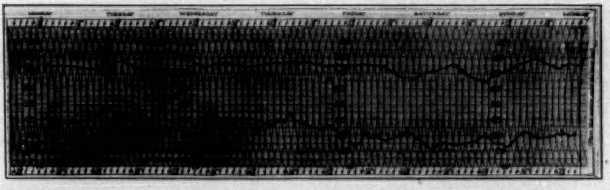
those which are diffused by the bacteria on the slide, these organisms therefore appear beneath the microscope as intensely illuminated bodies on a dark field. Both the microscope and polarizing microscope are of value to the chemist. The saccharimeter serves for the determination of sugars in the optical way; the Dubuscq colorimeter is used in the colorimetric determination of creatin and creatinin, the spectroscope is utilized in the

FIG. 5.



Hygrothermograph record—chill room—mechanical refrigeration. The upper curve is a record of relative humidity, the lower curve of temperature Fahrenheit.

FIG. 6.



Hygrothermograph record—laboratory. The upper curve is a record of temperature Fahrenheit, the lower curve of relative humidity. The two charts here reproduced are a record of the temperature and the relative humidity of the chill room and of the laboratory for the same week. It will be noticed that in the chill room the two curves, temperature and relative humidity, are practically parallel, while in the labratory the two curves are more or less independent of each other, and occasionally may go in opposite directions at the same time.

study of the absorption spectra of natural coloring matters, and the Abbe and immersion refractometers provide an excellent method for the determination of the index of refraction. The egg-candle is a form of optical apparatus, hitherto considered as of commercial value only, which makes possible a study of the physical condition of the egg in the shell, including the position of the yolk with respect to the white, the motility of the

yolk and the density and opacity of both white and yolk; it also reveals " rots " and " spots."

The temperature of the electric muffle furnace, which is used in the determination of ash, is measured by means of a thermo-electric pyrometer. The thermograph furnishes a permanent record of the temperature of the room, chill room, ice box, cold storage or refrigerator car in which it may be placed. The hygrothermograph provides a means of obtaining a permanent record of both the temperature and the relative humidity. The freezing point of milk has to be determined to the thousandth of a degree Centigrade, therefore recourse is made to the freezing point apparatus of Beckmann.

The eudiometer finds application for measurement of the volume of oxygen liberated from hydrogen peroxide by the enzyme catalase. To reduce the volume of the oxygen to standard conditions, the barometric pressure must be known; therefore, the laboratory is provided with a barometer. By means of the torsion viscosimeter, the viscosity of a liquid may be determined. The Westphal balance is occasionally used for the determination of the specific gravity of liquids, although a pyknometer is usually employed for that purpose. Needless to remark, the laboratory is provided with several balances and a full supply of graduated glassware including burettes, reservoir burettes, pipettes, flasks, a Muter tube for the isolation and study of liquid fatty acids, and several Gottlieb Röse tubes for the quantitative determination of milk fat.

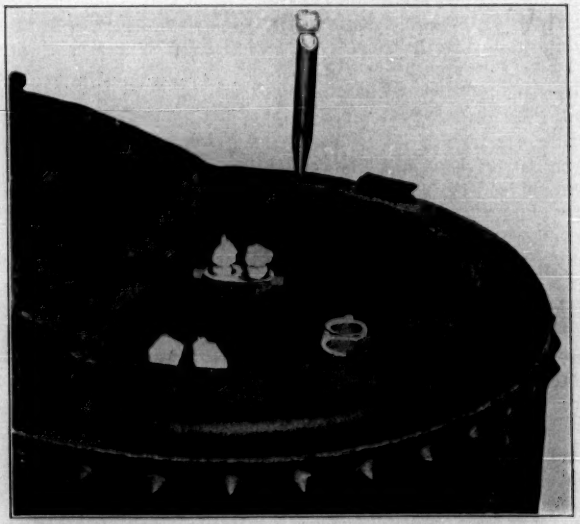
BACTERIOLOGICAL WORK.

Various researches in bacteriology have been carried out. A study has been made of the bacterial content of fresh birds and during marketing, while the relative number of organisms in the wall of the abdominal cavity of drawn and undrawn fowls has become the subject of special investigation. The number of bacteria present in fresh eggs as well as their species, have been determined; and the rate of growth of micro-organisms in milk kept at low temperatures has also been studied.

The investigation of the bacterial content of poultry while hard frozen may be taken as a type of these researches. The technic first had to be developed. Samples of flesh from the pec-

toralis minor muscle were removed from the birds with sterile instruments and weighed in tared sterile flasks containing fragments of glass. A definite volume of sterile physiological salt solution was then added and the flask was shaken for 10 minutes, by which time the meat was disintegrated by the action of the glass and water. The resulting suspension was plated. Plates

FIG. 7.



Centrifuge—equipped for bacteriological work. On the right is an empty carrier with two compartments, each of which holds a pointed, cotton-plugged, glass tube such as is seen on the top of the centrifuge. The front and back carriers are loaded with such tubes. The fourth carrier is beneath the lid on the left, and is not visible.

were poured in the usual way to obtain the total number of obligate aërobes (micro-organisms requiring free oxygen for their development) and facultatives (micro-organisms developing in either the presence or absence of free oxygen). The total number of facultatives and obligate anaërobes was ascertained by the double-plate method of Wright. The latter are micro-organisms

which develop only in the absence of free oxygen. The spore-forming micro-organisms which commonly give rise to putrefaction are able to resist a temperature of 80° C. for 10 minutes; the suspension was therefore subjected to those conditions, then plated by Wright's method to determine the number of these organisms present in the flesh.

Roasting and boiling chickens of known history, both drawn and undrawn were kept hard frozen for four months at a temperature of —10° C. "In every case bacteria were present in the muscles of the breast and thigh, and the walls of the abdomen, though usually the number was small and the great majority of the organisms were of the aërobic type. Very few bacteria resistant to 80° C., were found and not one of those appearing on Petri plates, poured according to Wright's method, proved to be obligate anaërobes, when subjected to further tests. Neither was gas produced, when the suspension of the flesh of the fowls was added to glucose bouillon in fermentation tubes."[1]

Market chickens which had been kept frozen for periods varying between fourteen months and four years were also examined. The fowls which had been hard frozen for fourteen months and seventeen months had a high bacterial content, and the presence of bacteria in their thigh muscles could be demonstrated histologically. In these birds there was noted "a marked tendency toward a relative increase in the number of bacteria developing at 20° C., as compared with those developing at 37° C."[2]

Later studies which have included the investigation of trade methods of preparing poultry for market as well as the fact that a delay in putting the produce into the freezer is often practised by ignorant merchants, would indicate that the findings quoted were due to bad handling before freezing, not to the effects of prolonged freezing itself. It has also been demonstrated, however, that deterioration begun in flesh before subjecting it to low temperatures is not completely checked by cold.

The chickens of known history kept hard frozen for four months showed a tendency toward an increase of the types of organisms which proliferated at 20° C., though it was much less marked.

[1] Premier Congres International du Froid, 1908, ii, 232.
[2] Premier Congres International du Froid, 1908, ii, 240.

Living bacteria were present in chickens kept hard frozen for four years, as was shown by the plating methods, although they were not revealed by histological analysis. The proportion of these organisms which developed when the plates were incubated at 20° C. was large; either the organisms developing at higher temperatures had been destroyed by the long exposure to low temperatures, or else the forms able to resist cold had increased. The birds which were hard frozen for four years, as well as those frozen for two years, contained more organisms able to resist a temperature at 80° C., than did the fowls which were kept for shorter periods.

These researches prove "that organisms can survive for long periods at temperatures far below the congealing point and that growth is prompt and vigorous when a suitable environment is provided."

Later researches have shown that even if a chicken be kept in a chill room at a temperature of about 32° F. for twenty-four hours after killing, bacteria will then be present in the flesh adjacent to the bones and in the muscles directly beneath the skin. A study of the penetration of muscle by organisms is now in progress.

HISTOLOGICAL STUDIES.

A histological study of chicken muscle has revealed a progressive change in the microscopic structure during storage in the frozen state. A longitudinal section of the muscle of fresh chicken is characterized by a wavy appearance; the line of demarcation between the fibres is very faint and the cross markings though visible are not especially striking. After storage for even one month, histological changes have occurred which become more pronounced as the period of storage increases. The wavy appearance of the longitudinal section disappears; the cross markings become brighter; the fibres pull apart, and material resembling coagulated foam appears between both the fibres and the bundles of fibres. After storage for three months this pulling apart of the individual fibres reaches such a stage that capillaries, which run parallel to the fibres, may be traced for long distances by means of the nuclei of their walls and the blood corpuscles within them. At the end of five months, some of the fibres have changed to a homogenous material; a breaking of

the sarcolemma or muscle sheath may occur, accompanied by an exudation of this homogenous material. The exudate is a fine granular precipitate, containing here and there displaced nuclei and blood-corpuscles and shreds of blood-vessels. Transverse cracks appear in the fibres after storage for five months; at ten months the fibre is broken into very short transverse segments; and at twelve months the tissue consists of short pieces of fibres dislodged from their normal positions and in fragments. With age, the brittleness of the muscle increases. These changes suggest autodigestion.

During decomposition at ordinary temperatures, the histological changes differ greatly from those occurring during prolonged freezing. Even when putrefaction is far advanced, though a pulling apart of the individual fibres may take place to a certain extent (due probably to dessication), yet neither interfibre material nor exudate has been found between them. During putrefaction the cross markings have not been intensified, and short, broken segments are far less frequent than in frozen birds. While certain fibres may be annihilated and thus give rise to empty spaces, during decomposition at ordinary temperatures, yet the former position of the fibre is never indicated by a homogenous mass such as occurs in hard frozen fowls.

Decomposition at ordinary temperatures gives rise to an odor of putrefaction, while storage in the frozen state leads to the development of a biting odor, recalling that of a mild rancidity. This odor is probably located in the fat.

ZYMOCHEMICAL INVESTIGATIONS.

Since enzymes play a prominent part in the natural changes which occur in foodstuffs, certain researches have been carried out in the field of zymochemistry. Thus a study of the occurrence of lipase in the crude fat of chickens is now in progress. the enzymes of milk, *e.g.*, catalase, oxidase and peroxidase, have also been studied.

[NOTE.—Part II, "The Scientific Study of the Handling of Perishable Foodstuffs," and Part III, "Select Methods of Analysis" will appear in early issues of the JOURNAL.]

THE MATERIALS OF PAINT MANUFACTURE.*

BY

G. B. HECKEL.

DURING recent years we have become somewhat familiar with the term "Scientifically Prepared Paint," and have heard or read some controversy over the propriety of the term. I hope to show before I finish that the term is justified and that prepared paint is not only a product of science and civilization, but that it is also a result of progress and evolution, as much as any other modern product.

An English writer has said of paint making that it was first an art, then a trick, but that now it has become a science. I have here a relic of the earliest known American Paint Makers—probably the same people who built the mysterious mounds of the Mississippi Valley. It is an axe or hatchet of hematite, and if properly crushed and ground would make a good grade of iron oxide. It was found in a tunnel uncovered at Lesley, Missouri, by modern miners who are still taking oxide from the same vein. Iron oxide was one of the pigments known to the aboriginal. He reduced the native hematite to powder, mixed it with oil, grease, mucilage or gums and applied it as a heraldic decoration to his face or wigwam, or used it in the crude decoration of his household utensils.

The history of all races in the use of paint is practically the same. The first pigments used are the natural earth colors or simple vegetable dyes. They are devoted to personal decoration—commonly heraldic—and later their use is extended to other decorative purposes. It is only in a higher stage of development and civilization that the protective value of paint is recognized. This evolution is the natural accompaniment of change from the nomadic state, where dwellings are temporary, to the fixed life of civilized society.

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* Presented at the Meeting of the Section of Physics and Chemistry held Thursday, March 30, 1911.

Let us consider a typical high grade paint formula. It contains the following ingredients:

ANALYSIS OF PEA GREEN.

(United States Standard Measure.)

	PER CENT.
Pigment by weight	48.00
Thinner by weight	52.00
	100.00
Thinner is composed of:	
Linseed oil	85.00
Asphaltum spirits	3.00
Turpentine	1.00
China wood oil	2.00
Japan dryer	9.00
	100.00
Composition of pigment:	
Hydrocarbonate of lead	15.00
Basic sulphate (white lead)	20.00
Zinc oxide	44.00
Silicate of magnesia (asbestine)	3.00
Calcium carbonate	2.00
Barium sulphate (blanc fixe)	10.00
Silicate of alumina	3.00
Lead chromate	2.30
Ferro-ferri cyanide of iron	.70
	100.00
Coloring is composed of:	
Pure chrome green	100.00
Composition of Japan dryer:	
Kauri gum	1.67
Lead oxide	8.45
Black oxide of manganese	2.00
Linseed oil	26.44
Turpentine	61.44
	100.00

Besides these ingredients that are mentioned on the label, we may also notice that the container is made of tin plate; that the can is soldered; that the labels are printed with two colors of printing ink on white paper, and pasted on the can. Finally we may recall

that such cans are packed with sawdust in wooden boxes nailed together with steel wire nails. Keeping in view the finished can and its contents, I think you will catch my drift, when I say that all science and all civilization have gone to the making of the can of paint bearing this label and that without science and civilization it would be unthinkable.

Let us consider briefly the ingredients, one by one: The first is linseed oil, a product of the flax plant, *Linum usitatissimum*. The flax plant was not first cultivated by man for the seed or its oil. Its earliest use was for the making of linen cloth. The great masters of early European art knew nothing of linseed oil, and the first use of the seed was medicinal. To-day in the United States alone over twenty-five million bushels of flaxseed are consumed annually in the manufacture of linseed oil, the great bulk of which goes to the production of paint and varnish. To produce so much seed requires from two million to two and one-half million acres of soil. Its cultivation requires many farmers and laborers, much special machinery; its storage and transportation utilizes elevators, railroads, steamships; its use for oil-making requires elaborate plants, much special machinery; and the treatment of the oil for its various uses involves chemistry and the mechanical arts. Moreover the oil-growing flax is itself a product of agricultural science, which is to-day more ardently pursued by plant specialists than ever before. The proper preparation and use of linseed oil involves the results of profound study and investigation, which to-day are still far from completion.

In the manufacture of linseed oil the flaxseed, cleaned from foreign seed and other impurities, is first ground in a series of roller mills. The resultant meal is treated in a special heater with live steam to break up the oil cells. This hot meal is then pressed into the desired form and size for the oil presses, in a cake former; and a number of those cakes are stacked, one above the other, in camel's hair or other fabric cloths, between the plates of a specially devised hydraulic press. An enormous pressure is applied and the expressed oil is filtered and collected in settling tanks, where the moisture, plant mucilage, etc., settle to the bottom, while the clear oil collects on top and is drawn off and sold as raw linseed oil.

Linseed oil is a very complex organic chemical compound, but consists essentially of the glycerides of a number of fatty

acids. Of these the most important in connection with our subject are the glycerides of linolic and linoleic acids, to which the oil owes its characteristic property of absorbing oxygen and thereby becoming converted to linoxin—the characteristic rubber-like product of "dried" linseed oil.

The presence of certain metals facilitates this process, and these metals are incorporated with the oil by heating their compounds with the raw oil. Recent investigations indicate that the only two metals practically effective for this purpose are lead and manganese, and consequently advanced manufacturers have generally abandoned the use of other compounds.

It will be noted that the liquid portion of our paint contains 85 per cent. of linseed oil. The fact is significant, for while linseed oil leaves something to be desired when we contemplate the ideal paint, it is nevertheless the most satisfactory paint oil for general use known to us up to the present time.

The remaining fixed oil in our formula is China wood oil, of which only 2 per cent. are present. China wood oil is comparatively a recent addition to the raw materials of paint and varnish manufacture. It is expressed from a nut grown on a tree (*Aleurites cordata*) indigenous to the Yangtze Valley, in China. The variety producing the oil nut is known to the Chinese as *ying tzu tung* (apple fruit Tung) and the tree is cultivated by the Chinese farmer for its oil. It grows to a height of about 25 feet, bears large green leaves, small pinkish flowers and large green fruit somewhat resembling an apple. The seeds are large and poisonous, and from them the oil is obtained. The machinery used is primitive, consisting essentially of a wooden press operated by wedges. The oil is traded, along with other agricultural products, to merchants at Hankow, Fatchau and Canton. It has been used in China for ages, much for the same purposes as linseed oil is used in this country, and it is said that the extracted seed residues are the raw material for the manufacture of India ink.

But little is as yet known generally regarding the chemistry of this oil. It has drying properties similar to a certain extent to those of linseed oil, and the rate of hardening is accelerated by the same agencies that promote the oxidation of the more familiar oil. The chemical process appears, however, to differ, since while

linseed oil hardens progressively from the surface inward, China wood oil seems to harden or set simultaneously throughout. This peculiarity led to rather expensive disasters in the earlier attempts to utilize the oil in this country. The drying salts are incorporated in practice at a comparatively low temperature; but in these earlier experiments the oil was treated at the temperature common in the treatment of linseed oil, with the result that the entire batch suddenly thickened to the consistency of rubber, in the kettle.

While the use of this oil is still the subject of experiment, it has established for itself an important place in the varnish industry, and is making rapid strides in the paint industry. It is believed that it adds a certain desirable solidity to the paint film and is especially valuable when rosin or resinates are present in the Japan dryers.

The two volatile ingredients of our formula are asphaltum spirits and turpentine. Asphaltum spirits is one of the lighter products of petroleums having an asphaltum base. It corresponds to the benzine which is produced from petroleums with a paraffin base. The chemistry of these hydrocarbons, while interesting, plays no part in the chemical structure of the paint film, since their office is purely mechanical and they disappear completely in the drying of the paint. As is well known, the petroleums found in some localities yield on distillation at high temperatures, residues containing paraffin, while similar oils from other localities yield asphaltums as residues. The best known petroleums of the latter class are those produced in Texas, California, and the Island of Borneo. Petroleums are distilled by fractionating, the products passing over at the lower temperatures being classified progressively as petroleum ethers, naphthas and gasolenes, and benzines. At still higher temperatures the illuminating oils pass over, followed by the lubricating oils. Asphaltum spirit is the benzine of the asphaltum petroleums. It boils at a higher temperature than the corresponding paraffin product, has a higher specific gravity and is, on many accounts, far preferable as a volatile ingredient of paints. I personally believe that the formula before us is mechanically improved by the presence of this material and I am convinced that it is in no way injured by it.

Turpentine is the essential oil of certain pines, principally

Pinus Australis, growing over large areas of our Southern States. It is distilled in a current of live steam from the sap of this tree, the residue being rosin. The industry, owing to the character of the labor available in the pine districts, is crude and wasteful both to the timber involved and to the product, though more conservative methods are coming into use through the efforts of the United States Department of Agriculture.

The negro workman in a turpentine orchard cuts a so-called "box" on one side of the tree, in which the sap collects, and from which it is from time to time dipped and carried to the still. As the flow of sap decreases, the bark is removed and the wood scarified higher and higher above the "box." In the larger trees several boxes are cut at different points on the circumference, weakening and in time killing the tree. The crude sap or gum is charged into a still with water, and on heating, the volatile turpentine passes with the steam to the worm condenser. The turpentine is decanted from the condensed steam on which it floats.

Turpentine in paint probably acts in two ways: first, as a volatile thinner, of which the effect is purely mechanical; and secondly, as a conveyer of oxygen, perhaps catalytically. At any rate it was the conclusion of a French technical commission who investigated the subject, that turpentine hastens the drying of paint to an extent not accounted for by its volatility.

The principal turpentine forests of to-day are located in Florida, southern Georgia and Louisiana, the immense forests that formerly covered vast areas in North and South Carolina and northern Georgia having been largely destroyed by the wasteful methods in vogue. Another form of turpentine has appeared in the market during comparatively recent years. It is familiarly known as wood turpentine, being produced, by various methods of distillation, from pine wood wastes. When properly prepared and purified, there appears to be no practical difference in its properties as a paint vehicle from those of sap turpentine.

The remaining liquid ingredient of our formula is Japan dryer. This consists essentially of the linoleates of lead and manganese, with a small percentage of Kauri gum. It is prepared by boiling linseed oil with the proper percentages of compounds of manganese and of lead adding thereto a certain quantity of melted Kauri gum, and reducing the product while warm, with turpentine, benzine or a mixture of the two. The lead compound used

in this dryer is red lead and the manganese compound is the black oxide, while the reducing agent is turpentine and Texas benzine—asphaltum spirit.

The manufacture of red lead leads us at once into the mining regions of the West, where in some districts lead is produced from practically pure ores, while in others it must be separated from its commingled silver, zinc, etc.

For the manufacture of the so-called Dutch Process white lead it is necessary to have the metal free from silver, manganese and iron; but for the manufacture of the ordinary oxides purity is not so important. The metallic lead comes from the smelter in the form of pigs, which are melted in a low flat oven in which the lead spreads out in a thin layer and is mechanically worked so as to expose continually fresh surfaces to the action of the air. The product is the monoxide of lead—massicot. This oxide is ground with water to remove metallic particles, which are returned to the furnace, while the oxide is collected in settling tanks. If the temperature in the furnace rises too high it becomes litharge—crystalline lead monoxide—which cannot be further oxidized.

The amorphous monoxide, being further treated in the same or a similar oven, at a low red heat, with free access of air and constant stirring, gradually takes up more oxygen and is converted into red lead—a combination of the monoxide and the dioxide, in the proportion of about two parts of the former to one of the latter. The product is usually stated as having the formula Pb_3O_4, but red lead is, as noted, a mixture of oxides rather than a definite chemical compound.

The black oxide of manganese, known to mineralogists as Pyrolusite, is a natural product, of which the principal sources of supply are in the Caucasus Mountains, in the Hartz Mountains and elsewhere. Chemically it is the dioxide of the metal manganese. The miners are the wild mountaineers of eastern Europe, and the mineral before it reaches America, passes through southern Russia, the Black Sea, the Dardanelles, the Mediterranean and so across the Atlantic. For the use of the varnish and dryer manufacturer it is subjected to mechanical purification.

These two metallic oxides readily replace the glycerin in linseed oil at moderate temperatures, forming oleates and linoleates, while the glycerin is decomposed and driven off.

The addition of a resin—in this case Kauri gum—at a moderately high temperature also probably induces the formation of resin acid compounds of the metals.

The driers made with lead and with manganese have sharply distinguished properties, of which advantage is taken by the well-informed manufacturer, who knows that certain proportions of the two yield better average results than either alone. He also carefully calculates the percentage of the metal in the drier to the oil to be oxidized. Kauri gum, besides helping the quality of the japan, has also been shown by experience to serve a useful purpose in paints containing high percentages of zinc oxide. It is found only in New Zealand where ancient forests of the tree which produced it—the *Dammara Australis* and other varieties of Dammara—have been buried for ages in the earth. It is mined systematically by trenching and is cleaned, sorted, and classified by hand.

We have now briefly covered the liquid portion of our formula and in the course of our survey have gone to North Dakota for flaxseed, to Florida for turpentine, to Texas for benzine, to China for wood oil, to Colorado and Montana for lead, to the Caucasus for manganese, and to New Zealand for Kauri gum. Even at this point we may begin to see that for this ordinary can of mixed paint the manufacturer has been under the necessity of calling upon many industries, several races and different quarters of the globe. It is no less so with the remaining items of our formula and the package in which it is sold. Lead hydrocarbonate is the first named of the solid ingredients. In this case it happens to be Dutch Process White Lead.

Lead hydrocarbonate or basic lead carbonate is a molecular combination of the hydroxide and the carbonate of lead in about the proportion of two parts of the latter to one of the former, though these proportions are only approximated in actual practice. The accepted formula, however, is $2\,PbCO_3$, PbH_2O_2. Of the three processes used to any extent for the manufacture of this product, two employ acetic acid in an intermediary step of the chain of reactions, while the third dispenses with it.

The Old Dutch Process, so called—though it has undergone great improvement in English and American practice—starts with desilverized lead pigs, known in the trade as "soft lead." These are melted, and the molten lead is distributed on shallow

moulds on an endless chain belt. The moulds give the metal the form of a flat circular grating or buckle about $^{3}/_{16}$ inch thick by 5 inches in diameter. These buckles are packed into earthenware pots, having at their bottoms shallow wells containing each about half a pint of vinegar or dilute acetic acid. These pots are arranged in tiers between layers of spent tan bark, where they are allowed to remain undisturbed for about 130 days. By the fermentation of the tan bark heat is generated and carbonic acid liberated. The heat vaporizes the acetic acid, which attacks the lead, coating the buckles with basic lead acetate. This in turn is attacked by the carbonic acid, producing the basic carbonate and liberating neutral lead acetate, which attacks the metallic lead beneath, producing again the basic acetate. The process thus continues progressively until most of the buckle has been altered to the basic carbonate. The buckles being removed from the pots are subjected to mechanical treatment which separates the corroded from the uncorroded portions. The white lead being ground, washed, floated and dried, enters commerce as dry white lead. The special characteristics of corroded white lead are its excellent working properties and low oil consumption, giving a high degree of opacity or color-body in the finished paint.

The second process, commonly known as the "quick process," also starts with desilverized pig lead. This is melted and finely comminuted in a steam blast, and the granulated product is charged into large, slowly revolving wooden drums, where after being moistened with dilute acetic acid it is subjected for some hours to the action of purified carbonic acid gas from burning coke. The slow revolution of the drums insures the exposure of the entire mass to the action of the gas. The chain of chemical processes involved is probably identical with those described for the Old Dutch Process. The mechanical treatment of the crude corroded product is essentially the same. The finished product is more uniform in the size of particle than Dutch Process Lead and finer in texture. This involves a larger oil consumption and a consequent decrease in opacity or color body of the completed paint.

The third process, known as the Mild process, because of the fact that acetic acid is not used, is applicable to pig lead of any description. In this process, also, the metallic lead is finely comminuted in a steam blast. In both this and the preceding

process there is a preliminary surface hydration produced by the action of the water vapor on the lead particles. The finer particles are charged into revolving drums containing water and there subjected to the action of air under low pressure for several hours. The lead is thereby converted into the basic hydroxide. This hydroxide is then subjected in similar drums to the action of purified carbonic acid gas for the requisite time, until the conversion to the basic carbonate has been carried to the proper point. The product is extremely white, uniform and pure, requiring only floating and drying to fit it for use.

The second pigment of our formula is Basic Lead Sulphate or Sublimed White Lead. As indicated by its title, this is a sublimation product, and is produced directly from the native ores of Missouri—lead sulphide—by oxidation at a high temperature in a current of air. The comminuted ore is charged in a special furnace with coal or other fuel and is subjected to a hot-air blast. The sulphide takes up oxygen, volatilizes and is carried through a series of cooling flues to fabric bags, in which it is collected. This is the process in outline, though not in detail. The reaction involved is simple: the lead sulphide, PbS, takes up four equivalents of oxygen from the air, being converted into lead sulphate, $PbSO_4$. At the same time it is also claimed, with much probability, that there is formed a certain proportion of the basic lead sulphate, $Pb_3S_2O_9$. At any rate analysis always yields an excess of oxygen, which is usually calculated to lead oxide, the percentage of which ranges from fourteen to twenty. The product, furthermore, always contains a small percentage (five to six) of zinc oxide, which comes from the zinc sulphide associated with the ores used. It may be said in passing that lead sulphate, chemically produced, is a very unsatisfactory pigment, exhibiting none of the characteristics of sublimed white lead. The latter, on the other hand, is extremely useful, and in certain combinations has come to be regarded as almost indispensable. The particles of this pigment are extremely fine and uniform, approaching the particles of zinc oxide in this respect. As a pigment, it stands between corroded white lead and zinc oxide in most of its characteristics. Paints made with it chalk more freely than paints made with the former, but on the other hand, they retain their color better, and do not "check" so freely. Proper

combination with zinc oxide restrains the characteristic chalking, while the hardening peculiar to zinc is in turn restrained.

Our third pigment is Zinc Oxide. Zinc is peculiar in that it is the only metal in common use produced by distillation. It is volatile at an easily attainable temperature and advantage is taken of this fact in recovering the metal from its ores. The hot metallic vapor is also readily oxidizable, and if exposed to the air, will take fire, burning with a green flame to zinc oxide.

The oxide is produced by two different processes. One, known as the French Process, taking advantage of the fact just mentioned, volatilizes the metal in a current of air, and collects the resultant oxide in closed chambers.

In the other process, known as the American process, the oxide is produced directly from the ores. On the nature of the ore used depend the individual characteristics of the resultant oxide.

In this process the comminuted ores are mixed with powdered anthracite and charged into closed furnaces having perforated grate bars. Combustion is started in the anthracite and a blast of air is forced through the perforations in the grate. The heat smelts the ore and volatilizes the zinc, and the metallic vapors promptly combine with the oxygen of the blast, producing zinc oxide. This oxide is carried through a series of cooling flues and collected in fabric bags. The particular oxide used in this formula is made from New Jersey ore, and on that account is of some interest. This ore is unique in that it occurs in commercially available quantities, nowhere else in the world. It is known as Franklinite, and consists of the oxides of zinc, manganese and iron in molecular proportions—crystallizing as a true mineral. It is closely associated in the vein with other compounds of zinc—the anhydrous silicate, the oxide, etc. A peculiarity of the product is that the oxide recovered is practically free from impurities, averaging over 99 per cent. pure oxide. The oxides produced from other available ores usually contain from 5 to 15 per cent. of lead sulphate, due to the presence of lead sulphide in the vein.

The characteristics of zinc oxide are too well known to require extended comment. It is the finest and whitest of all white pigments; is chemically quite stable, the only chemical changes possible in practice being to the sulphide or to the carbonate, which are also white. It is bulky and hence carries a high percentage of

oil in the finished paint; and finally when properly used is very durable. One is fairly safe in saying that if Oxide of Zinc had not been introduced as a pigment, there would have been no prepared paint. It was produced as a commercially available pigment, in answer to a demand that had been voiced in Europe from the closing years of the Eighteenth Century, to the time of its introduction about the middle of the nineteenth. This demand for a non-poisonous white pigment finally received a satisfactory response from a contracting painter of Paris, Le Claire, who was also celebrated as a philanthropist and is known to this day as "the father of profit sharing." Practically every great chemist of Europe from Lavoisier to Faraday had his try at the problem.

Our next pigment is the silicate of magnesium, in the form of asbestine. This product comes principally from Canada. Its usefulness in the paint formula depends entirely upon its physical form, which is acicular or rod-like. Its office in the paint film has been compared to that of the hair in plaster or the rods in reinforced concrete. It is without special value either for opacity or protection, but aids in holding the materials in suspension and very probablly also in resisting stresses in the dried paint film.

Our fifth solid ingredient is Calcium Carbonate—in this case a natural product from Missouri—a dolomitic crystalline rock, finely ground for the purpose. Calcium carbonate, as used in paint manufacture, comes to us in two forms. Whiting, Paris White, etc., are the pulverized and floated chalk supplied principally by the chalk cliffs around Dover, England; the calcareous skeletons of innumerable diatoms that once populated the waters of an ocean covering that portion of the earth, ages before the advent of man; while the product used in this formula is from a similar geological source, but in succeeding epochs subjected to heat and pressure, which gave it a crystalline structure. As a rule manufacturers in selecting from these two forms are governed by the conditions; if the remaining inert pigments are crystalline, Paris White is selected; if not, then the so-called mineral primer is preferred.

Either will neutralize any free acid in the paint, but the mineral primer will in addition give the "tooth" which is thought desirable in the manual work of painting. The only other crystalline pigment in our formula is the asbestine, so mineral primer rather than a form of chalk has been selected for this formula.

Barium Sulphate is the next on our list, and is used in the form of the chemical precipitate—blanc fixe. Personally, I should have preferred the natural crystalline form, barytes, in this case, but that is a matter of detail. The sulphate of barium in the form of barytes is a natural, crystalline product, which retains its crystalline form, no matter how finely comminuted.

It is found associated with lead, zinc and other ores in most mineral regions. That used in the United States, however, comes principally from Missouri and the Alleghenies in central Virginia, Missouri furnishing the larger proportion. There its production is in the hands of farmers who collect and cart it to the railroads in the fall and winter, to be manufactured into pigment at St. Louis and neighboring points. In the Allegheny regions the mineral is procured by mining.

Blanc fixe is produced by transforming the natural product into a soluble compound and precipitating it from dilute solution with sulphuric acid or a soluble sulphate. The product is chemically identical with barytes, but physically very different, being very finely divided and amorphous.

Silicate of alumina is the next ingredient of our white base. Technically it is a washed and floated China clay, naturally produced by the disintegration of certain feldspars, the soluble potash salts having been washed away. The percentage here used is small, but it has a physical influence on the suspension of the other pigments, in the brushing qualities of the paint and on the quality of the paint film.

The remaining ingredients of our formula are the colors required to produce the desired tint. They have no influence on the quality of the paint. The yellow in this combination is lead chromate—chrome yellow. It is produced by the reaction of a soluble chromium salt, usually sodium bichromate, on a soluble lead salt, usually lead nitrate, both in solution. The neutral chromate of lead, $PbCrO_4$, being insoluble, is precipitated. The production of this familiar pigment again takes us far afield. The chromium used in making the chromates is obtained from an ore of iron known as chromite. It is a chromate of iron, having the composition $FeCr_2O_4$. It is found in small quantities in Pennsylvania, Maryland, California and elsewhere in the United States, but the main sources of supply are Asia Minor and New Zealand. Large quantities of these ores are imported into Eng-

land, Germany and the United States for the sole purpose of manufacturing the chromium salts of potassium and sodium. The process is intricate and difficult, so that the manufacturers are few in number. There is also some demand for the mineral in the manufacture of special steels.

The remaining pigment is Prussian Blue—the potassio-ferro-ferri-cyanide of iron. This material brings us once more into the field of organic chemistry, the non-metallic component of the blue being cyanogen, which is most familiarly known as a component of hydrocyanic or prussic acid and the cyanides of potassium, etc. The chemical composition of the color is indicated by the formula, $K_2Fe_2{}_2FeC_6N_6$.

The cyanides are obtained from animal wastes containing carbon and nitrogen, such as dried blood, leather paring, hoofs, horns, etc. These are calcined with an alkali and the ash lixivated with water, and from this liquor cyanides of the alkali metal can be recovered, or the blue may be directly obtained by precipitating with ferrous sulphate (copperas). In practice, in the manufacture of chrome green as used for tinting in the present instance, the colors are precipitated simultaneously from solution, either with or on the base, which in this case is the blanc fixe shown in the formula.

We have now glanced hastily at the characteristics of our several ingredients, but they are still only raw materials and require a long series of mechanical operations before our can of paint will be readly for use, not to mention the detailed work of the chemist to determine the quality of the materials themselves.

A modern paint factory is a complicated institution, and in the limits of such a paper as this can only be touched upon briefly and hastily. Power in the most modern plants is generated at a central point and is distributed to the units in the form of electrical energy. As a rule the raw materials are elevated to the highest point in the plant, so that the product, in its several steps towards completion, may fall by gravity from each point to the next in the process.

The dry pigments are ground separately to the form of a paste with linseed oil. The various components of the white base are then thoroughly incorporated with more oil, the whole is then mixed with the rest of the oil and the remaining thinners in a mechanical agitator, the tinting colors being added either

here or at the preceding step, and the exact tint is attained by addition on the judgment of the expert tinter. The finished paint is measured mechanically into tin cans, which are also soldered and labelled by machinery, and finally these cans are packed in cases holding a given number and guarded from injury by sawdust, placed between them. The boxes are then nailed shut, marked and shipped to the distributors. This is the mechanical routine in the barest outline; but we may observe that it involves the use of building materials, fuel, copper wire, tinplate, paper, printing-ink, paste, box lumber, sawdust, wire nails, etc.

The manufacture of tinplate is an important industry in itself, involving a branch of the steel industry in the production of the plates for this use. These plates are cleaned by chemical means, heated, and coated with metallic tin by dipping in a bath of the molten metal. To obtain the tin for this use we must again go to distant regions. Tin ores are found in small quantities in various parts of the United States. I have in my own collection interesting specimens from South Dakota, West Virginia and Alaska; but so far no commercially available quantities have been found in these localities.

Cornwall, from the time when the Phœnicians traded to Britain for tin to the days of the first McKinley tariff, was the chief source of the world's tin supply. But the drain finally told on the natural resources, and the bulk of the tin consumed to-day comes from the Straits of Malacca and from Australasia. In the former locality it is recovered by placer mining methods and in the latter by the usual methods of underground mining. The ore is found in two forms, as the oxide, Cassiterite, and as the sulphide, Stannite, in which latter form it is associated with iron. The smelting of the ore for the metal is done principally in England and other parts of Europe.

The paper for our label is a product of sulphite wood pulp as is most of the paper used for advertising paint. We need not enter farther into this subject except to note that our industry involves also the paper manufacturing industry.

Similarly we may note in passing that the printing ink manufacturer and through him the lampblack manufacturer, the color maker and the varnish manufacturer are involved.

Finally, in the consumption of paste, we return once more to the farmer on whom we called in the first instance for our linseed

oil. In order that I may not be suspected of straining for effect when I include these items in the enumeration, it will be interesting to know that in the year 1909 one paint manufacturer reports to me the following items:

Paper for labels	$ 2,520.00
Paper for advertising matter	18,840.00
Black and colored ink for labels and advertising matter	2,736.00
Solder for soldering tin cans (of which again tin is a constituent)	125,227 pounds
Output of colored samples	33,236,542 pieces

For 1910 these figures should all be increased by about 20 per cent.

Adhesion of Electro-deposited Silver to German Silver Basis Metal. A. MCWILLIAM AND W. R. BARCLAY. (*Inst. of Metals*, Jan. 1911.)—The peeling of the silver deposit in high grade plated goods when subjected to severe conditions of wear was investigated. Heavy deposits of silver were made, under similar conditions, on various grades of German silver, and the finished articles subjected to a cold bending test. The thicker the silver deposit was, the greater was its tendency to strip off under the strain. The so-called higher grades of basis metal, containing over 14 per cent. of nickel, were found to be of doubtful utility from this point of view, the deposits were much more adherent on the lower grade alloys. This view was confirmed by microscopic examination; so that it seems advisable to avoid too high a percentage of nickel in the basis metal for high grade electroplate which has to endure rough usage. Although these alloys poor in nickel are neither so white nor so strong as the richer alloys, the color is of small importance when there is a heavy deposit of silver, and sufficient strength can be attained by proper mechanical and thermal treatment of the alloys.

Silver Finish on Aluminum. DR. ROBERT GRIMSHAW. (*Metal Ind.*, ix, 9.)—To bring out the color to the fullest degree dip the article in a solution of sodium hydroxide at a temperature of 110° F. to 125° F., rinse in water, and carefully brush with a brass wire brush, keeping the article moist with a solution of soap-root and water. Again dip in the soda solution, rinse with water, re-dip in the soda, rinse again with water, then dip in a solution of three parts nitric acid with three parts sulphuric acid, and finally rinse in water, Then dry the article in sawdust free from resin (bass wood is best) and lastly burnish.

FRANKLIN INSTITUTE

(*Proceedings of the Stated Meeting held Wednesday, May 17, 1911.*)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, May 17, 1911.

President WALTON CLARK *in the Chair.*

Additions to membership since last report, 2.

Joseph S. Hepburn, A.M., M.S., presented the paper of the evening, entitled "The Handling, Transportation, and Storage of Perishable Foodstuffs. A review of the Work of the U. S. Food Research Laboratory."

An outline of the work of the laboratory was given from its establishment several years ago to the present time. The apparatus and equipment first installed and those now in use were described in detail, as well as the chemical, bacteriological, and histological investigations made in connection with the study of poultry.

The effect of low temperatures and storage on the tissues and muscles of poultry were shown by means of photomicrographic slides. Numerous lantern slides illustrating the best methods of killing and preparing poultry for the market, the most approved manner of packing and shipping, and recent practice in cold storage, were exhibited.

The thanks of the meeting were extended to the speaker. Adjourned.

R. B. OWENS,
Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

(*Abstract of Proceedings of the Stated Meeting held Wednesday, May 3, 1911.*)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, May 3, 1911.

DR. GEO. A. HOADLEY *in the Chair.*

The following reports were presented for final action:

No. 2455.—Hardinge Conical Ball and Pebble Mill. Certificate of Merit. Adopted.

No. 2458.—Colby Electric Furnace for Melting Metals. Scott award. Adopted.

No. 2479.—Behrend High Speed Electric Generators. Scott award. Adopted.

No. 2501.—Wolf Liquid Gas Apparatus and Process. Scott award. Adopted.

R. B. OWENS,
Secretary.

SECTIONS.

Section of Physics.—The Stated Meeting of the Section was held in the Hall of the Institute on Thursday, May 4, 1911, at 8 P.M., with Dr. E. Goldsmith in the Chair. Forty-seven members and visitors were present. The minutes of the previous meeting were read and approved.

Dr. Robt. H. Bradbury of the Southern High and Manual Training High School of Philadelphia presented a communication on "The Teaching of Elementary Chemistry" in which he discussed the two classes of text-books on elementary chemistry—the "conventional" and the "Nature-study" types. He drew the conclusion that a proper combination of the two types in a single text-book is the ideal plan. Dr. Bradbury recommended that the element sulphur and its compounds be made the subject of the first lessons in elementary chemistry, also that laboratory exercises in this branch of the science be carried out by the student as far as possible in a quantitative manner. The lecture was illustrated with experiments.

Dr. Goldsmith, Dr. Keller and Dr. Bradbury participated in the discussion. A vote of thanks was tendered Dr. Bradbury, and, on motion duly seconded, the meeting adjourned.

JOSEPH S. HEPBURN,
Secretary.

Mechanical and Engineering Section.—A meeting of the Section was held on Thursday evening, May 11, 1911, at 8 o'clock, President Walton Clark, Temporary Chairman. Present 75 members and visitors. The minutes of the previous meeting were read and approved.

The paper of the evening entitled "Metering Steam and Gas" was read by Prof. Carl C. Thomas of the University of Wisconsin, Madison, Wis. The flow of fluids and gases in pipes was first given consideration. Extracts from the papers of Pole, dated 1851, were presented and reference was made to the formulæ of Unwin Oliphant Coxe and Lowe. The mechanisms of various meters for gas, natural gas and compressed air were described and illustrated by numerous lantern slides.

A discussion followed the reading of the paper in which Messrs. Gartley, Crisfield, Leeds, Ledoux and the Chairman participated. The thanks of the meeting were extended to the Speaker. Adjourned.

ALFRED RIGLING,
Acting Secretary.

Mechanical and Engineering Section.—A meeting of the Section was held on Thursday evening, May 18, 1911, at 8 o'clock. Dr. E. Goldsmith, Temporary Chairman. Present, 80 members and visitors. The minutes of the previous meeting were read and approved.

Mr. Wilfred Lewis of Philadelphia presented the communication of the evening on "Machine Molding." Brief mention was made of the early patents on the subject beginning with one for a machine for molding screws issued over a century ago. Lantern views of various types of molding and jarring machines were shown and described. Hand and power molding was compared and it was shown by time cards that machine molding requires one half the time of hand molding.

The subject was discussed by Messrs. Stratton, Thorne, the Chairman and the Speaker. On motion, duly seconded, the thanks of the meeting were extended to Mr. Lewis. Adjourned.

ALFRED RIGLING,
Acting Secretary.

MEMBERSHIP NOTES.

Election to Membership.

RESIDENT.

MR. HAROLD C. HEILMAN, Philadelphia Iron Works, 412 N. Eighteenth St., Philadelphia.

NON-RESIDENT.

MR. EDWIN M. CHANCE, Philadelphia & Reading Coal and Iron Co., Pottsville, Pa.

Changes of Address.

MR. WHARTON BARKER, Port Royal Avenue, Roxborough, Philadelphia.
MR. WM. T. DONNELLY, 17 Battery Place, Room 930, New York City.
MR. BYRON E. ELDRED, 149 Broadway, New York City.
MR. PETER LOBBEN, 289 A St., Boston, Mass.
MR. ALFRED J. MAJOR, The Sedgley, Forty-fifth and Pine Sts., Philadelphia.
MR. JOHN E. NETHERY, 2025 W. Turner St., Philadelphia.
MR. W. M. WHITE, 375 Lake Drive, Wilwaukee, Wis.

NECROLOGY.

Mr. Charles Wallace Hunt, president of the C. W. Hunt Company and past president of the American Society of Mechanical Engineers and of the United Engineering Societies, died at his home, Staten Island, March 27, 1911.

Mr. Hunt was born at Candor, Tioga County, New York on October 13, 1841. He received his early education at Homer, New York, afterwards studying higher mathematics and mechanics under a private tutor. In the year of his majority he entered the military service of the Government, serving mostly in Virginia, from 1862 to 1865.

Upon his release from Government service about 1868, he engaged in mechanical pursuits and, after a few years of general experience, commenced the manufacture of machinery for handling materials on Staten Island, N. Y. in 1872. The result was the development of the now widely known plant of the C. W. Hunt Company, devoted to the production of a large variety of devices for saving labor in the handling of materials.

In addition to this large plant there were established plants in England and Germany for the manufacture of machinery designed by him.

He was deeply interested in the American Society of Mechanical Engineers of which he was elected one of the vice-presidents in 1892 and President in 1898. He was also a member of the American Institute of Electrical Engineers, The Franklin Institute and a number of other societies.

Mr. Spencer Meade.

LIBRARY NOTES.

Purchases.

INDEX TO ELECTRICAL LITERATURE 1893–1903.

The Library has recently acquired a valuable collection of some 40,000 printed abstracts of and references to, all the current electrical literature published in the electrical and numerous other scientific and engineering journals of this country and abroad, during the eleven years from 1893 to 1903 inclusive.

It is a complete collection of all the abstracts and references published in the *Digest of the Electrical World* during that period, during which it was compiled and edited by Mr. Carl Hering, it being the original collection made by the compiler for his own use.

Each abstract is on a separate card; the cards are classified into groups and sub-groups according to subject and date, and are contained in a cabinet of nine long double drawers of the usual style, thus making them very convenient for references and searches.

The years over which these abstracts extend include the periods of greatest development of many of the important branches of electrical science and engineering. In most cases the abstracts contain the substance of the original articles, papers or notes, together with the conclusions, occasionally accompanied by cuts, and the collection is therefore not a mere index of references, but contains in itself a very large amount of data and information.

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Illinois State Geological Survey, Bulletin No. 16. Year-Book 1909. Urbana, 1910. (From the Survey.)

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BOOK NOTICES.

LES MACHINES A ECRIRE. Par Jean Rousset, Ingenieur Civil. 180 pages 7½ x 4¾ inches with 58 figures, paper. (Encyclopédie scientifique des Aide-Mémoire.) Gauthier-Villars, Paris 190. Price, paper 2 francs 50, cloth 3 francs.

Although the typewriting machine has been universally adopted, literature on the subject is apparently as meagre as the subject is of wide-spread interest. But few monographs containing analyses of these machines are

available and for explicit data search must be made through patent records and technical periodicals.

In this small volume, without attempting an exhaustive treatment, representative models are described and the mechanism employed in effecting their various functions are analyzed at considerable length, preceded by a most interesting outline of their origin and development. A particularly valuable feature, and one that should save much labor in investigating the state of the prior art, consists in the numerous references to original patents throughout the text, by the name of the inventor and year of patent. As is customary in the other volumes of the excellent series to which this monograph belongs a bibliography is appended. The completeness and extent of the data collected, despite the small compass into which it is condensed, are evidence that the subject has been elucidated by thoroughly competent hands and, as on previous occasions, the editors have shown rare discrimination both in their selection of subject and author.

GOOD ENGINEERING LITERATURE. What to Read and How to Write, With Suggestive Information on Allied Topics. By Harwood Frost, M. Am. Soc. M.E., M. Soc. Prom. Eng. Educ. Cloth, 420 pages 7½ x 5 inches. Price $1.00 net. Published by the Author. Distributing Sales Agents, Chicago Book Company, Chicago, 1911.

It is generally conceded that the quality of the literary productions of members of the engineering profession suffers by comparison with that of other professions. The necessity of rigid analytical method in the study of engineering problems tends often to discourage rather than stimulate what is commonly known as style. This and the often meagre inspiration to be derived from an engineer's environment may explain a considerably greater deficiency than is usually found. There is no royal road to the acquirement of a good literary style, and when one who is deficient in literary training is called upon in the course of his professional duties to express his thoughts in writing, precisely, clearly and in good form, there is no alternative but to devote the requisite time and effort to a study of the subject.

Although Mr. Frost's work is avowedly intended to lend a helping hand to engineers struggling with the difficulties of composition, only a slight attempt is made to give instruction on this subject and so may prove disappointing to many. The work will be found most useful to those who have mastered fundamentals and are called upon to perform editorial duties such as the preparation of manuscript for publication, the reproduction of illustrations, considerations of topography and other matters involved in the production of printed matter. A number of other topics of value incidental to editorial duties are included; among others, the relation between author and publisher, indexing and filing, literary criticism.

For the editor's office the book contains many valuable suggestions; for the literary novice, it serves to point out the difficulties which beset him and indicates where remedies may be sought.

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The Flight of Birds. By Giovanni A. Borelli. 40 pages, illustrations, plate, 12mo. Aeronautical Classics No. 6. London, Aeronautical Society of Great Britain, 1911. Price, in paper, one shilling net.

A Course of Qualitative Chemical Analysis of Inorganic Substances with Explanatory Notes. By Olin Freeman Tower, Hurlbut Professor of Chemistry in Adelbert College of Western Reserve University. Second edition, revised. 84 pages, 8vo. Philadelphia, P. Blakiston's Son & Co., 1911. Price, in cloth, $1.00.

Chemistry of Food and Nutrition. By Henry C. Sherman, Ph.D., Professor in Columbia University. 355 pages, 12mo. New York, The Macmillan Company, 1911. Price, in cloth, $1.50.

Traité d'analyses chimiques métallurgiques a l'usage des chimistes et manipulateurs de laboratoires d'acieries Thomas. Par J. Hognon, Ingenieur-chimiste diplome, 155 pages, illustrations, 8vo. Paris, Gauthier-Villars, 1911. Price, in cloth, 5 francs.

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U. S. Department of Agriculture. Farmers' Bulletin, No. 403. The Construction of Concrete Fence Posts. Prepared by the office of public roads. 31 pages, illustrations, 8vo. Washington, Government, 1910.

Manila, P. I., Bureau of Science. Eighth annual report to the honorable Secretary of the Interior by Richard P. Strong, for the year ending August 1, 1909. 62 pages, plate, 8vo. Manila, Bureau of Printing, 1910.

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U. S. Bureau of the Census. Forest products No. 3. Slack cooperage stock, 1909, compiled in co-operation with the Department of Agriculture, Forest Service, Henry S. Graves, Forester. 14 pages, 8vo. Washington, Government, 1911.

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U. S. Commissioner of Education. Report for the year ended June 30, 1910, vol. 2, 663-1373 pages, 8vo. Washington, Government, 1911.

CURRENT TOPICS

Radiation of Sound from Explosions. G. V. DER BORNE. (*Phys. Zeitschr.*, xi, 483.)—It has been observed that in the immediate vicinity of sources of sound of great intensity there is a region of *normal audible-distance*, then a zone about 100 kilometres wide where the sound is inaudible, followed by a very greatly extended region of *abnormal audible-distance*,. The explanation of this is that in the lower or foundation layers of the atmosphere in which the temperature falls as we ascend and the molecular weight of the air is practically constant, the sound rays are concave upwards. In the higher layers they are concave downwards and accordingly return, because in the higher regions of the atmosphere there is a larger proportion of the lighter gases, hence the molecular weight of the air is less, and the speed of sound greater. The wind has only a slight influence in these phenomena.

Chemical and Physical Effects of Pressure Uniform in All Directions. G. SPEZIA. (*Accad. Sci. Torino.*, Atti. xlv, 335.)—A mixture of finely divided copper and silver, maintained for one month under a uniform pressure of 8000 atmospheres, does not show the slightest sign of combination, and since the cupriferous deposits at Keveenaw Point contain copper and silver, which have been in intimate contact under pressure for a very long time, the author considers that Spring's theory that high pressure alone is sufficient to cause combination of these metals, is inaccurate. Experiments with wax, which Spring found to flow like water under a pressure of 700 atmospheres, show that no liquefaction or semi-liquefaction takes place with a uniform pressure of 9900 atmospheres for 12 days. The author criticizes the conclusions of Spring and Kahlbaum that increase of pressure causes a diminution in density of certain substances; the fact that copper used by Kahlbaum changed its shape on compression proves that the pressure was not uniform; for a wax prism, compressed in a water bath, maintained its shape after exposure to a uniform pressure of 3200 atmospheres for 24 hours.

First Roechling-Rodenhauser Furnace in the United States. ANON. (*Iron Age*, lxxxvi, 1439.)—An induction electric furnace, of this type will be installed by the Crucible Steel Casting Co., Lansdowne, Pa. It will be of 2 tons capacity, with a single-phase 25 cycle current, furnished by a generator driven by a 425-horse-power oil engine. Cold material will be charged for a time, later a cupola may be used for melting the scrap.

Petroleum Deposits on the Coast of the Gulf of Suez. (*Les Matières Grasses*, iv, 2129.)—It has long been known that petroleum deposits existed on the west coast of the Gulf of Suez, but they have been considered unimportant, as the borings at Jebel Zeit proved unsuccessful. Within the last two years fresh borings have been made in the peninsula of Jemsah, about 165 miles from Suez. At the depth of 1265 feet a fountain was struck, which threw up a column of oil 100 feet high. Analysis shows this oil contains a large proportion of petroleum spirit (benzine) and is free from water. Another well at Jemsah is yielding 600 tons per day (estimated). As these wells are near the coast, it is anticipated they will be worked in 1912. Reservoirs and refining works are being erected at Port Tewfik, near Suez. Experimental borings are being made at Jebel Zeit, in the islands of Gaysum and Taouila, and at Abou Zenima, which is only 60 nautical miles from the coast.

Influence of Lime on the Sulphur of Roasted Blendes. E. PROST. (*Bull. Soc. Chim. Belg.*, xxv, 103.)—Experimenting on the roasting of blendes, to which known proportions of lime were added, it was found in all cases that the more lime used the more sulphur was retained proportionately, and further additions to the charge of silica, lead oxide, or iron oxide had no appreciable effect on the decomposition of the calcium sulphate produced. Furnace trials confirm these laboratory results and indicate that nearly all the calcium present in the charge must appear as sulphate after roasting.

Influence of Nickel on Reactions. P. NEOGI AND B. B. ADHICÁRY. (*Z. Anorg. Chem.*, lxix, 209.)—Ramsay and Young stated that small quantities of ammonia are formed when a mixture of nitrogen and hydrogen is led over red-hot iron, but the writers find there is no formation of ammonia from its elements in presence of either iron or nickel provided the nitrogen is free from nitric oxide. Pure nitrogen is most conveniently prepared by heating a mixture of ammonium chloride and sodium nitrite and removing most of the nitric oxide from the resulting gas by passing it through a solution of ferrous sulphate. Then dry the gas and remove the residue of nitric oxide by passing it over hot metallic copper. Nitric oxide is reduced to ammonia, sulphur dioxide to hydrogen sulphide and phosphorus pentoxide to hydrogen phosphide by hydrogen in the presence of reduced nickel. The reaction for nitric oxide begins at about 300°C. When nitric oxide alone is passed over reduced nickel, no production of a nitride, nitrite or nitrate of nickel was observed, hence it is concluded that the nitric oxide is reduced directly by the hydrogen, the nickel acting as a catalyzer. When sulphur dioxide acts alone on nickel some nickel sulphide is formed. When phosphorus pentoxide is heated with nickel in the absence of hydrogen, nickel phosphide and phosphate are formed.

Dielectric Strength of Oil. H. W. TOBEY. (*Electrician* lxvi, 491.)—This paper treats of the dielectric strength of mineral oil with regard to its use in electric power transmission apparatus. The voltage at which the oil breaks down varies greatly with circumstances, and a carefully chosen system of measurements is necessary, particularly in the shape of the terminals, which should be, preferably, brass discs facing each other horizontally. The dielectric strength does not vary greatly with temperature except when the oil solidifies, when it rises considerably. The most important factor is the presence of small quantities of water, which lower the dielectric strength. This water should be removed. Free sulphur lowers the dielectric strength, but its chief importance lies in its corrosive action on the copper conductors. A valuable test for sulphur is to dip a polished copper wire in the oil and note the rate at which it blackens. Insulation resistance is not an indication of dielectric strength unless temperature be considered, since it falls rapidly as the temperature rises, while the dielectric strength rises very slightly.

Luminous Tubes of Neon. GEO. CLAUDE. (*Mon. Scient.*, lxxiv, 135.)—The remarkable luminosity of neon can be utilized for lighting purposes. One of the difficulties of the problem is the ease with which neon is masked in luminous tubes by small quantities of certain other gases. It is not sufficient to introduce very pure neon into a tube with electrodes, under suitable pressure, in order to obtain an effective luminous tube, for the gases disengaged from the electrodes and from the walls by the current almost destroy its luminous power. This can be overcome by the use in a special way of Dewar's discovery of the absorbent properties of charcoal at low temperatures. In fact neon is not so easily liquified as the other gases introduced or set free by the passage of the current, and is therefore less easily absorbed than they are by charcoal at the temperature of liquid air. In this way neon is purified, and after prolonged treatment the beautiful orange luminescence appears and retains its brightness. This bright light is very rich in red rays and is just the corrective required for the light of vapor tubes; in many cases it could be used alone as for studios, halls and so forth.

New French Time. (Notes *Rev. Scient.*, xlix, 216.)—The new legal time is thus defined by law: "The legal time in France and Algeria is 9 minutes 21 seconds later than the mean time of Paris." This makes French time agree with the international time of Western Europe, *i.e.*, the time of the meridian of Greenwich. It also makes French time agree with the time adopted by the French railroads, which have previously adopted the international time.

Radio-Activity of Thorium. E. RUTHERFORD. (*Chem. News*, ciii, 22.)—The thorium emanation produces activity in substances exposed to it, and breaks up at the rate of 54 sec. for half disappearance, so that in 10 minutes practically none remains. There are four solid products of its disappearance. The first "Thorium A" is produced by the expulsion of an α particle, and decays to half-value in 10.6 hours, a slower decay than that of any of the other products, "Thorium B–C–D," the last of which emits both β and γ rays. The first of the transformation products of thorium itself is "Thorium X." It falls to half-value in 3.6 days. The next product is "Radio-thorium" which falls to half-value in two years. Then comes "Meso-thorium" with a half-value period of 5.5 years. This has almost the same properties as "Thorium X" and emits β and γ rays, and from it radio-thorium is formed, which emits α rays.

Fireclay Ware. C. SCHÄRTLER. (*Sprechsaal*, xliv, 17.—The manufacture of fireclay sanitary ware is meeting with some success in Germany. Slip-casting reduces the cost of manufacture by one-third, and enables pieces 4 inches thick to be cast. An engobe is introduced between body and glaze, and is applied by an ærograph, which is said to cost only one-twentieth of the cost of brushing it on. A convenient length for the tunnel-kiln is 330 ft. which holds about 80 trolleys laden with ware; the journey through the kiln requiring 6 days. In charging the kiln with fuel avoid cold draughts, which are apt to crack the ware. The loss in manufacture should not exceed 10 per cent. from all sources. The goods nearest the fire are apt to get over-fired and the rest under-fired, owing to the obstruction of the flame by the ware.

Electrical Distribution in Massachusetts. ANON. (*Eng. Record*, lxiii, 178.)—Electricity was introduced into the State for illumination in 1880, both for streets and houses. This source of income proved unstable, so as a consequence there was soon a marked decrease in the number of generating stations relative to the areas supplied, and many of the companies underwent physical and legal consolidation. In 1888 there were 56 electric light companies, supplying 64 municipalities. At present there are 120 plants distributing electricity over 215 cities and towns.

Fluorescence and Band Spectra of Oxygen. W. STEUBING. (*Ann. de Physik.*, xxxiii, 553.)—A discussion and re-measurement of the fluorescence and band spectra of oxygen. He considers them in relation to Stark's theory of electrons and concludes that the negative band spectrum and the first band spectrum (λ3333–λ2449) are due to the atom of oxygen, while the second band spectrum (λ1919–λ1831) is due to the molecule of oxygen.

The Clinkering of Coal. L. S. MARKS. (*Eng. News,* lxiv, 623.)—After discussing the question of clinkering and the usual remedies, the investigation proceeds to discover the conditions under which the clinkering of a poor coal could be diminished. The results may be summarized as follows: The elements which cause clinkering are chiefly calcium, iron and sulphur. The exact amounts which may be present without causing trouble are not yet known with sufficient accuracy to permit the use of such a formula as Prost's with any security. In a general sense Prost's formula is correct, that is the fusion temperature rises as the alumina increases, and falls with the increase of the other elements, but it cannot be relied upon for any particular ash. The only real cure for clinkering is low temperature combustion. If the temperatures are high, clinkering can generally be reduced by the use of steam or by adding kaolin or quartz, but these are too expensive to be commercially justifiable.

Fusion of Carbon by Means of the Joule-effect. M. LA ROSA. (*N. Cimento,* xx, 302.)—A current of about 60 ampères at 150 volts was passed through carbon rods of 1, 2 and 3 mm. diameter, containing only 0.07–0.08 per cent. of mineral matter. If the full current is passed directly through the rod, explosion occurs, but by gradually raising the current by reducing the resistance, the carbon becomes luminous and bends slightly. By enclosing the carbon in a porcelain tube and then causing an explosion, stains are found on the sides of the tube, which under microscopical examination are apparently carbon. Though no complete liquefaction or crystallization of carbon has taken place, the results obtained are considered to indicate incipient fusion.

Color in Raw Rubber. D. SPENCE. (*India Rubber J.,* xli, 15.)—Spence does not agree with Kaye that the darkening of rubber is due entirely to enzymic action. The discoloration is probably due to the oxidation of polyhedric phenols, and it is emphasized that the velocity of oxidation depends not only on the enzymic activity, but also on the acid or alkaline reaction of the medium. The ease with which plantation Parà rubber can be obtained white is ascribed to the slight acidity of the medium.

Tellurides of Sodium and Silver. G. PELLINI AND E. QUERCIGH. (*Accad. Lincei,* xix, 350 and 415.)—By warming sodium and tellurium together in a quartz tube in an atmosphere of nitrogen, compounds of the formulæ Na_2Te, Na_2Te_2, and Na_2Te_7 were obtained. Thermo analysis of alloys of Ag and Te shows compounds of the formulæ AgTe and Ag_2Te. The former is produced at 444° C., is decomposed at higher temperatures and polymerizes at 412° C.; the latter melts without decomposition at 959° C. and does not polymerize.

Persulphates and Per-Salts. F. J. G. BELTZER. (*Mon. Scient.*, lxxiv, 78.)—Persulphates can be prepared chemically by double decomposition between barium persulphate and sodium sulphate in saturated solutions. Barium sulphate is precipitated and filtered, and the sodium persulphate rapidly evaporated and crystallized; or barium persulphate is treated with its equivalent proportion of sulphuric acid, at very low temperaturre to prevent the decomposition of per-sulphuric acid. Electrolytically persulphuric acid is obtained by the action of the current on sulphuric acid at a low temperature. Alkaline persulphates are produced by the electrolysis of acid alkaline sulphates. Other conditions being equal, the relation between hydrogen peroxide and persulphuric acid is exactly defined by the relation between water and sulphuric acid. Finely divided platinum and silver decompose persulphuric acid catalytically with explosive violence; powdered zinc, magnesium and carbon decompose it quietly; powdered iron has no action. Wool and cellulose are instantly carbonized with a hissing noise; cotton is inflamed by a few drops in a few seconds. The formula for persulphuric acid is $H_2S_2O_8$. A modification, known as Caro's persulphuric acid, has the formula $H_2S_2O_9$. The persulphates are energetic oxidizers, and are used as decolorizers, as disinfectants, and as oxidizing agents in explosives. When neutral or alkaline solutions of chlorates are electrolyzed with a platinum anode and a platinized-platinum cathode, without a diaphragm, perchlorates are produced, but acid solutions require a diaphragm. Linen can be bleached by the available oxygen of per-borates which is set free at a temperature between 50° and 60° C.

The Properties of Aluminum Magnesium Alloys. WITOLD. BRONIEWSKI. (*Rev. Scient.*, xlix, 91.)—The electric conductivity and the thermo-electric force shown by alloys of aluminum and magnesium determine the existence of the two compounds, $AlMg$ and $AlMg_2$ observed by Mons. Boudouard by means of the curve of initial solidification, and of the compound Al_2Mg_3 observed by Mons. Grube. The existence of the compounds Al_4Mg and Al_3Mg_2, has not been confirmed by the study of the electric properties.

Gageite, a New Mineral from Franklin, N. J. H. H. PHILLIPS. (*Am. J. Sci.*, xxx, 283.)—The specimens came from the Parker shaft and were associated with zincite, willemite, calcite and leucophenicite. The crystals are delicate, acicular, and hair-like, sometimes radiated and grouped in bundles protruding from the walls of small cavities. They are clear and colorless with a high vitreous lustre. Before the blowpipe gageite darkens to deep bronze or nearly black, but does not fuse. The crystals dissolve readily in dilute nitric acid. Their analysis is silica 24.71, manganese oxide 50.19, zinc oxide 8.76, magnesium oxide 11.91, and crystallized water 4.43 per cent.

Tantalum Lamps on Chicago Railway Cars. ANON. (*Electr. Rly. Journ.*, xxxvi, 1189.)—From an exhaustive series of tests, curves are given showing the fluctuations in voltage and current on the line circuit and particulars as to the way in which the durability and efficiency of the lamps were tested in actual operation. By the introduction of tantalum lamps a saving of not less than 5 cents per car-day, or $35,000 a year on the total cars of the company, was effected. Diagrams are given showing the period of renewal of the lamps, the miles run before replacement, etc., during different portions of the year. After extensive trials a variety of lamp was selected giving at 115 volts, 16 c.p. for 35 watts and 32 c.p. for 70 watts consumption. It is pointed out that in addition to the saving in energy consumption effected by the replacement of carbon lamps by tantalum lamps, the renewals per car-month are also less, viz., 2.21 as compared with 4.27.

Condensation of Radium Emanation. A. LABORDE. (*Le Radium*, vii, 294.)—If radium emanation be condensed at the temperature of liquid air, and the temperature be allowed to rise again, gas will begin to be evolved at about 20° C. lower temperature in a glass tube than in a metal tube. If a current of air carrying radium emanation be led at a constant velocity through a tube immersed in liquid oxygen 18 cm. long and 0.22 cm. diam. only 0.2–0.7 per cent. of the emanation escapes condensation if the tube be of metal (tin or copper), but 60–70 per cent. remains uncondensed if the tube be of glass. This does not seem to be due to the poor heat conductivity of the glass, for the condensation is greatly increased if a thin copper wire (0.024 cm. diameter) be placed inside it. If the glass tube be long enough it will condense nearly as well as a metal tube; 160 cm. of glass is about equivalent to 18 cm. of tin tube.

Colloidal Copper. A. RASSENFOSSE. (*Chem. Zentr.*, 82, 122.)—When anhydrous copper sulphate is dissolved in concentrated sulphuric acid, and alcohol added so as to form an upper layer, a violet zone, probably containing cuprous sulphate, is formed between the two liquids; the violet color gradually changes to brown owing to the production of a solution of colloidal copper. Methyl alcohol, ether, acetone, acetic acid and chloroform act in a similar way to ethyl alcohol. A solution of anhydrous copper phosphate in anhydrous phosphoric acid behaves in an analogous manner, on addition of an organic substance.

Life of Telegraph Poles. F. MOLL. (*Archiv. Post. Tele.*, xxiv, 673.)—After quoting many tables of figures the following conclusions are reached: Poles impregnated with zinc chloride have an average life of 12.1 years; with copper sulphate, 14.5 years; with corrosive sublimate, 16.5 years; and with creosote 22.2 years.

New Critical Point in Copper-Zinc Alloys. H. C. H. CARPENTER AND C. A. EDWARDS. (*Inst. of Metals*, Jan. 1911.)—The authors have detected pyrometrically, both in heating and cooling curves, the thermal change at about 470° C. found by Roberts-Austen in some copper-zinc alloys. It is not due to a eutectic. The change is a true critical point and is found in all alloys containing from about 63 to 40 per cent. of copper. At 470° C., on cooling, the so-called β constituent splits up into an intimate mixture of α and γ. On heating, the reverse change takes place. Alloys which just above 470° C. contain β are seen at a very high microscopical magnification, when cooled below 470° C., to contain α and γ. As γ is a very brittle constituent, the fact that the stable phase above 470° C. is β, and below this temperature $\alpha + \gamma$ has an important bearing on the cause of the brittleness and decay of many brasses in engineering work. It also explains the "crystallization" of pure α alloys, as α consists of copper $+ \beta$. The brittleness is entirely removed by annealing above 500° C.

A New Uranium Colloid. A. SAMSONOW. (*Zeit. Chem. Ind. Kol.*, viii, 96.)—In attempting to prepare uranous chloride by the electrolytic reduction of uranyl chloride, the author obtained besides the dark green uranous chloride solution, a black precipitate soluable in water. The solution of the black substance had the properties of a solution of an electropositive colloid, which proved to be uranous oxide, UO_2. It can also be obtained by the reduction of uranous chloride with zinc or copper in weak hydrochloric acid solution. Solutions of the colloid containing uranous chloride are much more stable than those free from that substance.

Method of Treating Carbon Electrodes. Patented by W. GASTON. (*U. S. Pat.* 979,465, 1910.)—The electrode is provided with a "second binder" by saturating the hot, finished, carbon electrode, immediately after it comes from the baking furnace, with a boiling solution of a liquid hydrocarbon, such as pitch or tar. The electrode is allowed to remain in the liquid until the cracks and pores have become thoroughly impregnated. The liquid hydrocarbon is retained as such, and automatically prevents the cracking of large carbon electrodes while in use.

Torgament Stone-wood Flooring. HENRY HESS. (*Amer. Mach.*, xxxiv, 122.)—This flooring is a plastic mass spread over an under floor of concrete. It is composed of Grecian cement (magnesite), asbestos, talcum and sawdust, with a binder of chloro-magnesium lye. The materials are carried to the place in powder, mixed with the lye to a thick paste and then spread with a trowel. Usually two applications are used, first a coarse, cheap composition and afterwards a denser composition which can be colored to taste. This torgament flooring is fire-proof.

On a Physical Interpretation of Non-Compensated Heat. (*L. Decombe, Comptes rend.*, clii, 315.)—A large number of modifications or of material transformations are accompanied by electrical phenomena; such as chemical reactions, mechanical deformations, the thermic variations of crystals, etc. The deformation of a substance can, moreover, cause the effective electrification of the different elements of its mass, without producing any external electric manifestation; provided that the axes of the couples so excited are oriented simultaneously in every direction, without any one of them becoming preeminent. The absence of free electricity, or of sensible electrical phenomena, does not permit the conclusion that electrification is absent, and it can be conceived that such absence is rather exceptional. The electron theory of matter is obviously favorable to this conception. Every material modification inducing a variation of the electrical momentum of the atom may be considered as giving rise to electrification; any changes occurring without a variation in the electrical momentum are characterized, on the other hand, by the absence of electrification. [Here follow mathematical proofs of the statement.] Hence, under these conditions, we are led to compare non-compensated heat to Siemens' heat, both of which are essentially positive.

The Electrical Measurement of the Modifications Produced by the Exposure of Bi-chromated Gelatin. HANS MAYER. (*Rev. Scientifique*, xlix, 211.)—The following conclusions were reached experimentally: (1) Exposure decreases the electric conductivity of bichromated gelatin. (2) This conductivity is enormously diminished by a normal exposure. (3) The conductivity increases with the increase of temperature, and the coefficients of temperature differ according as the plates are sensitized or not. (4) The conductivity of the plate varies enormously with the atmospheric humidity; therefore this source of error must be eliminated to obtain true measurements. (5) The conductivity decreases in inverse proportion to the time of exposure, whatever the initial degree of conductivity of the plate may be. (6) The sensitiveness of bichromated gelatin (expressed in degrees of conductivity) decreases with time, as the plates age; rapidly at first, then slowly, and at last becomes stationary. (7) After the exposure is ended, the conductivity continues to decrease for a certain time in darkness.

Silundum, Aloxite and Alundum. ANON. (*Mont. Scient.*, lxxiv, 13.)—Silundum is a dense and compact form of carborundum, with a higher conductivity. It is used in electric heating apparatuses.

Aloxite is obtained by heating bauxite in the electric furnace. It is an artificial corundum.

Alundum is another form of aluminum oxide, fused in the electric furnace.

Use of Preservatives in Food. J. C. THRESH. (*Proc. Seventh Int. Congr. Appl. Chem.*, 211.)—It is contended that generally speaking, the use of food preservatives, in reasonable quantity, has not been proved to exert any injurious effect on health, and that in many cases the use of such preservatives is justifiable. Against the conclusions of Dr. H. W. Wiley, it is urged that in the experiments on which these conclusions are based, (1) the preservative was not, save in the case of formalin, administered with the food but in single daily doses, enclosed in capsules; (2) larger quantities were administered than would ever be taken in preserved foods; (3) the controls were insufficient and inadequate. The author refers to a U. S. Report according to which benzoic acid and benzoates, in the quantities used for food preservation, neither injure health nor impair the quality or nutritive value of foods. He considers that in some cases (*e.g.*, milk) the use of preservatives is neither necessary nor desirable and that if legislative action is necessary, it should be directed to preventing the use of preservatives in such cases.

The Bristol Recording Thermometer. ANON. (*Iron Age*, lxxxvii, 213.)—This is a gas filled instrument with an automatic compensating device. The new instrument, known as Class III, has been adapted to record lower ranges of temperature, than the instruments previously in use. The compensating device enables the instrument to give an accurate record of the temperature being measured, irrespective of any changes in temperature at the recording instrument itself. It consists of a special, spiral pressure tube, a capillary connecting tube and a sensitive bulb, the bulb and the connecting tube being filled with an inert gas under pressure. Temperature changes in the sensitive bulb produce corresponding changes in the pressure of the confined gas, and these changes are measured and recorded by the instrument. To make any error due to changes in temperature along the connecting tube negligible, the volume of gas in the sensitive bulb is very large in proportion to that in the capillary connecting tube.

Influence of Boric Acid in Diaminophenol Developers. R. NAMIAS. (*Proc. VII. Int. Congr. Appl. Chem.* ix, 11.)—Boric acid may be advantageously used as a preservative agent for diaminophenol developing solutions. When 50 Gm. per litre is present, the solution can be used after several months, and their reducing power is not impaired to the same extent as it would be by the use of bisulphites. The time necessary for development is only slightly greater than when boric acid is absent, and the quality of the images is unaffected. If potassium bromide is added to the solution, the rate of development greatly decreases, and the contrasts increase, so this is a convenient method for developing over exposed images.

Wiltshireite, a New Mineral. W. J. LEWIS. (*Phil. Mag.*, xx, 474.)—Found in a cavity in dolomite associated with sartorite at Binn (Valais). Its color is tin-white, and though its chemical composition could not be determined from the small quantity available, it is thought to be a lead sulpharsenite.

The Echelette Grating for the Infra-red. R. W. WOOD. —(*Physik Zeit.*, xi, 1109.)—The method of making a diffraction grating of rather large grating space, 1000 to 2000 lines per inch, is described. They were ruled with a carborundum crystal, by a Rowland's ruling engine, on a gold-plated copper plate. The groove was V-shaped, which concentrates a large proportion of the incident energy in a direction making an angle of approximately 40° with the direction of the incident energy. It is proposed to name such gratings "echelette."

The Electrical Conductivity of Commercial Copper. F. A. WOLFF AND J. H. DELLINGER. (Reprint 148 from *Bulletin of the Bureau of Standards*, vol. vii, No. 1. Washington, D. C.)—The investigation recorded in this paper was undertaken in view of the very considerable variation existing between the coefficients of conductivity, resistivity and temperature of commercial copper in use by various institutions in different countries. The samples upon which measurements were made were wires Nos. 6 to 18, B. & S. gauge most of them No. 12—and about 120 cm. in length, supplied by representative producers at home and abroad.

SUMMARY OF RESULTS

1. The various standard values in use for the resistivity and temperature coefficient of copper are given, and the need for the present investigation shown.

2. The means of making precise measurements of conductivity of wire samples is described.

3. The resistivities are given for 89 samples of commercial copper from 14 important refiners and wire manufacturers in this and other countries. The mean for annealed wires is:

Resistivity in ohms per metre-gramme at 20°C. 0.15292
Per cent. conductivity.....100.07 per cent.

(Per cent. conductivity is computed on the basis of 100 per cent. conductivity corresponding to the standard of resistivity, 0.153022 ohm per metre-gramme at 20°C.) The mean result of data furnished by a large wire manufacturing company, representing tests on more than 100,000,000 pounds of copper, is also given, viz., for annealed samples:

Resistivity in ohms per metre-gramme at 20°C. 0.15263
Per cent. conductivity.....100.25 per cent.

It is concluded that the best value to be assumed for the resistivity

of *annealed* copper, in the preparation of wire tables and in the expression of per cent. conductivity, etc., is the previously used standard value, viz:

0.153022 ohm per metre-gramme at 20°C.

4. The conductivity of hard-drawn No. 12 B. & S. wires was found to be less than the conductivity of annealed wires by a mean value of 2.7 per cent. The difference between the conductivity of annealed and hard-drawn wires increases as the diameter of the wire decreases.

5. The lowest resistivity and highest conductivity found, for a *hard-drawn* wire, were:

Resistivity in ohms per metre-gramme at 20°C. 0.15386
Per cent. conductivity.....99.46 per cent.

and for *annealed* wire, were:

Resistivity in ohms per metre-gramme at 20°C. 0.15045
Per cent. conductivity.....101.71 per cent.

6. Representative mean values for commercial hard-drawn aluminum were obtained, as follows:

Resistivity in ohms per metre gramme at 20°C. 0.0763
Resistivity in micro-ohms per cm. cube at 20°C. 2.828
Density 2.70

7. The work on the temperature coefficient of resistance of copper, which is reported in another paper, was done upon samples included in this investigation. The temperature coefficient was found to be substantially proportional to the conductivity. This relation may be expressed thus: the change of *resistivity* per degree C. is a constant for copper, independent of the temperature of reference and independent of the sample of copper; this constant is

0.000598 ohm per metre-gramme.

8. The advantages of the expression of resistivity in ohms per metre-gramme are stated.

9. The desirability of an international standard of copper conductivity is urged.

Coke for Foundry Purposes. E. L. RHEAD. (*Eng.* xc, 107.) For foundry purposes coke should be (1) strong and hard, (2) dense, (3) of good cell structure, (4) as free as possible from ash, (5) should contain only a little sulphur, (6) should be uniform in texture. The best coke should not contain more than 0.7–0.8 per cent. of sulphur; if it contains more than 1.3 per cent. it is unsuitable for use in the cupola. High carbon coke with little ash and low sulphur, with suitable physical characteristics to enable rapid and complete burning in the smallest space, will insure the best results from the cupola by the rapid melting of clean, hot metal with the lowest possible fuel consumption. Coke should be kept dry under cover, for water introduced into the cupola means waste of heat. If the cupola is properly designed and the air supply properly regulated the coke cannot be too dry.

A New Mineral Water, and the New Physico-Chemical Methods of Examining Mineral Waters. ARMAND GAUTIER AND C. MOUREU. (*Comptes rendus*, clii, 546.)—In March 1909, a spring of mineral water, delivering 1870 litres per minute, was struck at a depth of 800 metres, in the Parc Sainte Marie at Nancy (France).

1. *Physical Examination.*—The color, limpidity, smell, taste, temperature, density, cryoscopic point, electrical conductivity, ionization and radio-activity were determined. In determining the electric conductivity, first the value K, given directly by the water, at 25° C., was ascertained, and then increasing volumes of distilled water of known conductivity were added to it, and the rate of the decrease in conductivity, consequent on the dilution was noted. Taking into account the mineralization of the water, and the conductivity of a solution of sodium chloride of approximately the same concentration, the degree of the ionization of the salts in this water was estimated at about nine-tenths.

For radio-activity, both the water itself, and the gases spontaneously disengaged (spontaneous gases) at the top of the ascending column of water, were examined by the Chéneveau and Laborde electroscope. The emanation of radium is expressed in milligramme-minutes in 10 litres of the gas and of the water. This was 0.46 in the spontaneous gases and 0.082 in the water. The radium as salts was estimated thus. The residue from the evaporation of a large quantity of water, after fusion with sodium carbonate, was redissolved in hydrochloric acid, raised to boiling to liberate the emanation, and left for several days in a closed vessel. The emanation thus accumulated was measured, and from this the quantity of radium in the water taken was calculated. Expressed as radium bromide there was found 0.012 mg. per 1000 cubic metres of water.

2. *Chemical Examination.*—There is nothing worthy of remark as concerns the reactions, the alkalinity, the dry residue and the sulphated residue.

Electro-positive elements, potassium, sodium, calcium, magnesium, iron and aluminum were determined by the well-known methods.

The following method was used for determining lithium. After concentrating 30 litres, the sulphates were precipitated by lead acetate, and the last traces by barium chloride. Calcium, barium, magnesium and ammoniacal salts were then separated, the dry mixture of alkaline chlorides was taken up three times by cold, concentrated hydrochloric acid, which dissolves all the lithium chloride and very little of the other chlorides; the hydrochloric extract was evaporated and treated with the *absolute alcohol amylic-ether* mixture, which dissolves the lithium chloride alone. The metal was finally precipitated as phosphate and weighed.

Traces of antimony and tin were found in the water, and the manganese was determined.

Electro-negative elements, sulphuric, hydro-sulphuric, phosphoric and carbonic acids, chlorine and silica were determined in the usual way.

Iodine was determined by the method described by one of us in *Comptes rendus*, cxxviii, p. 1069.

Bromine was determined by its liberation in a closed vessel, with the aid of heat, by chromic acid in presence of sulphuric acid; the liquid distilled, the distillate absorbed in a solution of potassium iodide; and the iodine liberated by the bromine titrated with hypo-sulphite.

Fluorine was determined by a hitherto unpublished method. After separating silica, calcium and magnesium the fluorine was precipitated as barium fluoride in alcoholic solution; the barium fluoride attacked by sulphuric acid, and the hydrofluoric acid set free determined as lead fluoride.

Boric acid was recognized by curcuma paper. Arsenic was determined by the method described in the *Bull. Soc. Chim.*, xxix, 859 by one of us.

Nitrates, nitrites, ammonium and organic matter. From the total nitrogen, determined by the Kjehldahl method, the ammoniacal nitrogen was deducted, thus determining organic nitrogen.

3. *Gases.*—(*a*) Spontaneous gases were determined over mercury. In 100 volumes of dry, natural gas, there were 1.75 volumes carbonic acid, and 98.25 volumes of a mixture of nitrogen, and the rarer gases, argon, krypton, xenon, helium and neon. These were recognized by their spectra. The 98.25 volumes of mixture contained 95.36 volumes of nitrogen, 1.29 volumes argon (with traces of krypton and xenon) and 1.60 volumes of helium (with traces of neon).

(*b*) Gases set free on boiling. Besides the ordinary gases, each litre of mineral water contained 0.45 c.c. of argon (with traces of krypton and xenon) and 0.19 c.c. of helium (with traces of neon).

Process for Rendering Celluloid Non-Inflammable. Patent by G. CHANDON DE BRIAILLES, No. 420,044, (French) 1909.—This process is particularly applicable to developed cinematograph films, celluloid in any form, and artificial silk. It consists of de-nitration under conditions which prevent shrinkage and deformation. The operation is conducted in a digester by the action of a solution of ammonium sulphide, ammonia and gelatin of suitable concentration and temperature. The liquid is forced into the material under a pressure of 10 atmospheres, developed by hydrogen sulphide gas. The strips of films are wound in a spiral on a plate carrying metal pegs surrounded by glass tubes, which hold the films apart. The camphor and nitro derivatives removed by the treatment are replaced by the gelatin, and thus shrinkage is prevented. The gelatin is subsequently rendered insoluble. Artificial silk is subjected to an after-treatment with boric acid.

A New Effect of Light. W. SCHEFFER. (*Brit. J. Phot.*, lvii, 705.)—The emulsion from ordinary films was softened in water, melted, diluted with water and examined under a microscope with strong illumination. When first exposed the halide grains show a motion like that of the Brownian movement, but after a few minutes' exposure this motion ceases, the grains disappear, and only larger, black, granular aggregates remain, resembling those produced by ordinary development.

A New Electric Furnace for Steel Melting and Refining. JOH. HARDÉN. E. E. (*Met. Chem. Eng.*, ix, 38.)—A combination arc and resistance furnace worked like an open-hearth furnace, which is adapted for crucible steel work, and for the highest grade tool steel. The slag-blanket is kept hot by arcs across the slag, while terminal plates transmit the necessary heat to the bath. For de-phosphorization and de-sulphurization any desired temperature may be attained without superheating the surface through the terminal plates. Controlling devices secure any desired gradient of heat. The threefold advantages of this type are; (*a*) the size of the electrodes is only about one-half that of an arc furnace of same capacity; (*b*) the maintenance cost is less, due to the two sources of heat and the smaller electrodes; (*c*) there is better control of the load factor of the furnace, because the current from the resistance plates is steady, and compensates for the large fluctuating arc currents. This furnace is economical because of low power consumption, standard electrical apparatus, and simple control.

Adjustment of Tension Members in Bridges. ANON. (*Eng. Record*, lxiii, 242.—Tension members which have become bent or slack have been straightened and shortened so as to take their proper share of the stress, by the thermit process. As described in the *Zentralblatt der Bäuverwaltung* the work is done without interrupting the traffic. Two clamps are attached to the tie, one above and one below the point where the shortening is to be done, and the clamps connected by two bolts. A two part mold is placed around the tie, the mold charged and ignited. The tie soon becomes white hot and the bolts are then drawn up to the desired degree. Tests made at the Royal Testing Laboratory, at Gross Lichterfelde, indicate that the metal is little impaired in strength by the thermit application.

Titanium Thermit. ANON. (*Mon. Scient., Mercure*, v, 21.)—This is an intimate mixture of aluminum and rutile (titanium dioxide). On igniting this mixture, a very high temperature is attained, with the production of ferro-titanium and alumina. It is advantageously used for purifying castings and converting them into titanium steels.

The Chemical Properties of Radium and Its Compounds. M. FORCRAND. (*Mon. Scient.*, v, 201.)—The little that is known of radium and its compounds fixes its position, as Curie did at first, in the barium series, as the heaviest of the alkaline-earths, with the atomic weight of 226.5. Its bromide is isomorphous with barium bromide, and both nitrates are equally soluble; radium chloride is a little less soluble in alcohol and in hydrochloric acid than barium chloride, and the carbonate a little less stable than barium carbonate. Madame Curie and M. Debierne have lately shown that the metal can be obtained by a process similar to that by which Guntz prepared barium; that it melts at 700°C., and forms a nitride which decomposes water in the cold, giving a soluble base. These facts fix the position of radium, between barium and sodium. The decomposition of water, in great excess, by metallic radium disengages between $+46.25$ ($\frac{Ba}{2}$) cal. and $44.1(\frac{Na}{2})$ cal., *i.e.* about $+45$ cal. for $\frac{Ra}{2}$ with disengagement of hydrogen in the cold; and the formation of an oxide a little more soluble than BaO and a little less soluble than Na_2O. This oxide, combining with water, forms a strong base Ra $(OH)_2$, which is a little more stable than Ba $(OH)_2$ and dissociates more easily than NaOH. The anhydrous oxide RaO is easily peroxidized at red heat to a fairly stable binoxide RaO_2; the heat of formation of which is about 19 cal. It combines with CO_2 to form a carbonate with the disengagement of about 70 cal. partially decomposed at bright redness. It is probable that the metal would combine directly with hydrogen to form the hydride RaH_2 with 17.6 cal.; reacting on water in the cold with the disengagement of hydrogen.

The Heroult Furnace in Germany. (Correspondent of *Iron Age*, lxxvi, 1430.)—The Lindenberg Co., of Remscheid, which holds the German patents for the Héroult electric furnace states in its annual report that this furnace is making steady progress in Germany. There are 23 furnaces now in operation and 17 in course of construction, three of them of 20 tons capacity. The 23 furnaces in operation produce 225,000 tons of steel a year. The Company claims to have worked out new metallurgical processes of far-reaching importance, and has applied for patents on them in all important countries.

Machine Blowing of Window Glass. E. JUSTUS MILLER. (*Amer. Mach.*, xxxiv, 403.)—The old hand process of making glass is now superseded by modern machines. The molten glass is placed in white hot clay pots and drawn and blown into cylinders thirty feet long, by hydraulically operated air blowpipes. These cylinders are slit, then flattened into sheets. It requires extreme care to produce clear glass. An interesting and instructive paper.

Monel Metal. J. F. THOMPSON. (*Eng. and Min. J.*, xci, 223.)—This alloy is made from the nickel-copper ores of Ontario and contains about 68 per cent. of nickel and a little iron. It is nearly as strong as steel and is as non-corrosive as copper or brass. The rolled metal is used for roof covering, screens and mining pump-rods. Large castings of monel metal are used for the propellers of turbine-driven ships. After a year's service this proved so satisfactory that the U. S. Government now specify this metal for propellers. Other navies use this metal. The cast metal has a tensile strength of 82,500 pounds per square inch, an elastic limit of 37,500 pounds per square inch and elongation 4.4 per cent. The modulus of elasticity is from 22,000,000 to 23,000,000 pounds as compared with 30,000,000 pounds for steel and 13,000,000 for manganese bronze. Castings can be produced up to 30,000 pounds weight in one piece. Its melting point is 1360°C., its specific gravity 8.87 (cast); electrical conductivity is 4 (copper 100); shrinkage ¼ in. per foot; hardness (cast) 22, (rolled) 27 by the Shore scleroscope. It retains its mechanical properties at a high temperature. At 1000°F. monel metal retains 80 per cent. of its tensile strength and elastic limit, while steel only retains 71 per cent. and manganese bronze only 60 per cent., while copper loses 60 per cent. at 780°F. This property led to its adoption for locomotive fire boxes in Germany.

The Chemist in the Brass Foundry. C. E. OTT. (*The Metal Ind.*, viii, 501.)—The chemist should be in absolute control of weighing, mixing and melting, for slight variations in weight often lead to faulty castings and other gross errors. He must have an accurate knowledge of the alloying properties of different metals and be able to produce alloys for any desired purpose. He must know what impurities are allowable and their percentages, and he must know how to eliminate these impurities if such a thing is possible. He must be acquainted with fluxes, their melting points and other physical properties. It is his duty to determine accurately, with the pyrometer, the temperature best suited for the pouring of the melt and then to make charts giving the weights of the various metals in an alloy and the temperature at which it should be poured.

Utilization of Wave Energy. ANON. (*Amer. Mach.*, xxxiv, 227.)—An Italian engineer, who is the inventor of a new sea motor for which great claims are made, states that the reason why the energy of waves has never been utilized is because it has never been recognized that they have a double force; one derived from the height of the waves' crests above the water level, and the other from the body of the waves as they roll in upon the shore. His invention utilizes both forces. It is reported that an investigation of the invention by the Italian Admiralty had favorable results.

A New Type of Electric Furnace.—*Abstract.* At the recent meeting of the American Electrochemical Society in New York, Mr. Carl Hering described a new electromagnetic phenomenon which he has named the "squirt phenomenon" and which he is using as the basis of a new type of electric furnace, for which he claims it is particularly well adapted.

This new phenomenon is as follows: If an electric current is passed lengthwise through a liquid conductor, like a molten metal which is confined in a tube or hole closed at the bottom by the electrode, and opening at the top into a bath of the molten material—then the liquid in the hole will be squirted out axially quite forcibly through the contral part of the open end, and other liquid will be forcibly sucked down into the hole around its periphery, provided the relation of the current to the cross section of the liquid conductor is sufficiently great. It may be said to be a valveless pump circulating the liquid rapidly throughout the hole.

If this hole is located in the bottom of a crucible or hearth and is so proportioned that the current will produce the necessary heat in the material in it, by virtue of its electrical resistance, the device will constitute a new kind of furnace, in which the liquid in the hole constitutes the resistor; it may be said to be a furnace with a "flowing resistor." The cooler liquid material flows down into this hole near the circumference, becomes heated by the current and is then at once expelled with considerable force to the top of the bath, where, in the case of the refining of steel, it comes into direct and intimate contact with the blanket of slag which takes up the impurities mechanically and chemically. In the furnace there are, of course, two such flowing resistors, one for each electrode.

The chief claims made for furnaces based on this principle are: greater heat economy, as the heat is all generated directly where it is wanted, without waste; much greater rapidity of refining, when the furnace is intended for steel refining, on account of the enormous and continually changing surface exposed to slag action; hence greater furnace capacity per day and greater heat economy, due to the shorter time of treatment; great homogeneity of the product due to the very rapid circulation; cheapness of construction, as the furnace consists merely of two holes in the bottom of a hearth, plugged with the two electrodes; no unnecessarily high temperatures with their attending heat losses; no consumption of electrodes with its attending costs; ease and nicety of regulation; no machinery for regulating an arc; applicability also to zinc and arsenic ores, glass, etc.; adaptability to being added to existing open-hearth furnaces or pots; possibility of adding fuel heat at the top of the lower temperatures; an arc may be added if desired; etc.

The force which produces this squirting action is caused by the so-called "pinch effect," described by the author some years ago, which is a radial force tending to contract the cross section of a conductor as though it were being pinched or squeezed; in the squirting phenomenon this radial force is made use of to produce

a pressure at the centre and a suction at the circumference, which in turn produce the upward and downward flows of the liquid. The forces were found to be surprisingly great, hence the heating may be made to be very rapid, as the heated liquids are expelled very quickly, the particles of the material being in the hole only a moment, probably not more than a second or two. Trial furnaces have operated very successfully.

Preserving Timber. ANON. (*Eng. Record,* lxiii, 310.)—The penetration of timber preservatives to be expected from the amounts of preservative usually specified are given by Mr. R. L. Allardyce, superintendent of the International Creosoting and Construction Co., of Texarkana, Tex., as the results of his experience. The figures refer to Southern pines treated by the full cell method. Bearing in mind the many variations in conditions, a fair average, based on numerous borings is given as ¾ to 1½ inches, in soft or sap wood for a 10 to 12 pound treatment on piling, using dead oil of coal tar; 1½ to 2½ or 3 inches for a 14 to 16 pound treatment; 3½ to 4 inches for a 20 pound treatment and 4½ inches to complete penetration for 22 to 24 pounds. In heart wood the penetration is less. In a straight zinc or Burnettized treatment of loblolly ties, a 20 pound treatment of a light solution is given for complete penetration, or up to the last 1 or 1½ inches from the centre. For short leaf or long leaf pine ties a stronger solution is recommended and never less than 100 pounds per square inch pressure during treatment.

Protection of Tools from Corrosion. ANON. (*Amer. Mach.,* xxxiv, 193.)—Tools can be kept clean and bright by coating then with mercurial ointment, known as "blue butter," which resists moisture. It should be handled carefully as it is somewhat poisonous. Another good resistent is made by heating 6 parts of lard with 1 part of rosin till the rosin is melted. Remove mixture from the fire to a safe place and add about 1 pint of benzine to each half-pound of the lard-rosin mixture. When cool, rub the mixture over bright steel articles. Tools treated in this way will resist the corrosion of even salt water.

Nitrification by the Ultra-violet Rays. D. BERTHELOT AND H. GAUDECHON. (*Rev. Scient.,* xlix, 314.)—The nitrification of aqueous solutions of ammonia, or of ammoniacal salts, or of nitrogenous organic bodies, can be caused by the ultra-violet rays in the presence of oxygen gas. The oxidation ceases at the nitrous stage, and inversely nitrates are reduced to nitrites. In concentrated solutions the reduction is carried still further, and as a particular case, ammonium nitrate disengages pure nitrogen gas. The ultra-violet rays act as ferments; and according to circumstances, cause a gain or loss of combined nitrogen.

The Combustion of Gaseous Fuel. (*J. Gas Lighting*, cxii, 711.)—An English patent has been applied for by Bone, Wilson and McCourt for an apparatus for burning an explosive mixture of two or more gases or vapors, so as to obtain complete combustion and to utilize the heat generated to the best advantage. This apparatus consists of a permeable diaphragm or refractory material in conjunction with a chamber or casing, the diaphragm forming one wall of the chamber, into which the gaseous mixture is led through pipes. The mixture passes through the diaphragm and is ignited at or near its outer surface. This apparatus attains very high heats by utilizing the accelerative influence of incandescent solids on gaseous combustion. The solids consist of (1) an outer shell of refractory material and a bad conductor of heat; (2) an inner bed of refractory material having interstock, into which bed the gaseous mixture is introduced and in which it burns; (3) an internal chamber, in which the heat generated is utilized; (4) a passage through which the carburetted gaseous mixture passes, of such dimensions in relation to the gas flow that the ignition of the combustible mixture shall not travel backward in the passage.—(Eng. Pat., 29430, Dec. 16, 1909.)

Purification of Boiler Feed Water Without Chemicals. ANON. (*Iron Age*, lxxxvii, 533.)—(A paper discussed by the Soc'y. of Chem. Industry, N. Y.) Mr. Thos. R. Duggan, of London, Eng., read a paper on the purification of boiler feed water, calling attention to the cost of chemical purification and the disadvantage of using chemicals in water to be used for brewing or dyeing. This led to the consideration of Herr Brandes' device for the softening of old scale and the formation of less new scale, known as the aluminator. The boiler feed water is run over an aluminum plate, at a certain slope and of various widths and corrugations according to the condition of the water. The theory is that a current of electricity is induced by the flow of water over the aluminum plate and the salts in the water are thereby ionized. The plate should be fixed in a north and south direction and exposed to the air. The advantages claimed are the prevention of hard scale, automatic action, absence of all chemicals, the metal of the boiler is unaffected, corrosion and pitting are avoided, fuel is economized, and free steaming obtained, at a very low cost.

Distinction Between Gutta and Rubber. G. HÜBENER. (*Gummi-Zeit.*, xxv, 634.)—Gutta and rubber behave differently towards chemical reagents. Ozone attacks solid rubber, but not solid gutta-percha. Rubber is easily vulcanized by sulphur, gutta is not; the affinity of gutta-percha for oxygen is much greater than that of rubber. Caspari's gutta-percha bromide is represented by the formula $C_{30}H_{46}Br_{10}$ and on heating to 130° C. is decomposed with evolution of hydrogen bromide.

Electrical Smelting of Iron Ore, Copper, etc., in Norway. (*Board of Trade J.*, Feb. 23, 1911.)—The Stavanger Electro-Staalverk Association with a capital of about $125,000, has been formed for the electrical production of high-grade steel from scrap iron and steel. Works will be erected at Jörpeland, near Stavanger, where a supply of 2500 h. p. of electrical energy has been secured, and this supply can be increased to 10,000 h. p. It is estimated that the annual output will be 1400 tons of high-grade steel billets, 600 tons of cast steel, 300 tons of hammered steel and 700 tons of scrap for re-smelting. The directors of the Tinfos paper mills have turned over the electric iron ore smelting concern at Notodden to the "Tinfos Jernverk, Asso." with a capital of about $275,000. The "Ass. Arendals Fossekompagni" has been established for iron smelting, under the management of Mr. Eyde. It is said to own the Böilo Foss waterfall, near Arendal, which can produce 30,000 h.p. of electrical energy, though only 12,000 h. p. will be harnessed to commence with. The Ilen smelting works of Trondhjem will begin the electrical smelting of metals using the process invented by their works director, Mr. Tharaldsen, starting with a 1000 h. p. furnace for copper smelting, estimated to produce 2000 tons per annum. A second furnace capable of producing 9000 tons per annum is expected to start in the spring. A consignment of 25 metric tons of pure, electrically smelted copper has been exported from the Birtavarra mines, at Kaafjord, near Lyngör. The "Kristianssands Nikkelraffineringsverk," Christianssand, is about to start the electrical smelting and refining of nickel and copper.

A New Arc Lamp. E. URBAIN, C. SCAL, AND A. FEIGE. (*Comptes rend.*, clii, 255.)—By striking an arc between a tungsten anode and a mercury cathode, 5 m.m. apart, in a vacuum or an inert gas, a very bright light is obtained similar to sunlight and very rich in ultra-violet rays. The spectrum is continuous with the mercury lines superposed. In vacuo the potential difference is 12 volts, but in the presence of an inert gas this can be greatly increased. The efficiency is about 0.45 watt per candlepower. The arc has a very high temperature which explains the necessity of using the very refractory metal tungsten as the anode.

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INDEX TO VOL. CLXXI.

Air, dry, saturated and unsaturated, Properties of, with application to cooling-tower and evaporative surface condenser calculations (Gebhardt), 165
Air-brake as related to progress in locomotion (Turner), 17
AKIMOFF, N. W.: Notes on the design of centrifugal pumps, 497
Alloys, Vanadium (Norris), 561
Archimedean principle, The application of the, to the exact determination of gaseous densities (Jacquerod and Tourpaian), 91

Battery, exide. The new iron-clad (Flanders), 287
Beams, A general formula for the shearing deflection of (Slocum), 365
Biochemical investigation, Soil organic matter as material for (Schreiner and Shorey), 295
BIZZELL, JAMES A., and T. LYTTLETON LYON: The relation of certain non-leguminous plants to the nitrate content of soils, 1, 205
BOOK NOTICES:
Duff, A. W.: Physical measurements, 108
Frost, H.: Good Engineering literature, 620
Gilbreth, Frank B.: Motion study, 429
Haanel, E.: Recent advances in the construction of electric furnaces, 109
Klein, H. O.: The applications of collodion emulsion to three-colour photography, 109
Morgan, A. P.: Wireless telegraph construction for amateurs, 108
Moritz, R. E.: College mathematics notebook, 532
Osborn, Albert S.: Questioned documents, 313
Rousset, J.: Les machines a écrire, 619
Smoley, Constantine, Smoley's tables, 428
BRINCKERHOFF, HENRY G.: Natural and artificial draft, 463

Camphors, Recent progress in the chemistry of the terpenes and (Hepburn), 179
Chemical affinity, The influence of, in certain phenomena called adsorption (Vignon), 87
Chemistry, Applications of, to public welfare (Wiley), 47
Conductor, The stretching of a, by its currents (Hering), 73
Copper deposits of Franklin-Adams Counties, Pennsylvania (Wherry), 151
CORRESPONDENCE:
Vacuum tube lighting (Gardner and Moore), 111
CURRENT TOPICS, 54, 72, 85, 86, 90, 93, 94, 112, 114, 149, 150, 163, 164, 177, 178, 204, 220, 242, 259, 260, 276, 286, 294, 316, 364, 390, 414, 431, 455, 456, 462, 496, 517, 518, 535, 559, 560, 614, 622
CUSHMAN, ALLERTON S.: The conservation of iron, 345

DAVEY, WHEELER P.: The mean depth at which Roentgen rays originate within a silver target, 277
DOLEZAL, EDWARD: Notes on the history of balloon photography, 301
Dow, L. S: Modern commercial food manufacture, 485
Draft, Natural and artificial (Brinckerhoff), 463
Drugs, The preparation and testing of (Pearson), 415

Electrical engineering, Some unexplored fields in (Steinmetz), 537

FLANDERS, L. H.: The new iron-clad exide battery for electric vehicles, 287
Food manufacture, Modern commercial (Dow), 485
Foodstuffs, perishable, The handling, transportation, and storage of (Hepburn), 585
FRANKLIN INSTITUTE:
Award of the Elliott Cresson medal to distinguished scientists, 95
Board of Managers, Annual report, 221

Committee on Elections and Resignations, annual report, 308
Committee on Instruction, Annual report, 222
Committee on Library, Annual report, 227
Committee on Meetings, Anuual report, 230
Committee on Publications, Annual report, 223
Committee on Science and the Arts: Abstract of proceedings of the stated meeting, Dec. 7, 1910, 103; Jan. 4, 1911; Feb. 1, 1911, 308; March 1, 1911, 422; April 5 and 12, 1911, 520; May 3, 1911, 615
Committee on Science and the Arts, Annual report, 230
Committee on Sectional Arrangements, Annual report, 224
Committee on Stocks and Finance, Annual report, 306
Honors by the, 113
Library notes, 106, 237, 311, 425, 530, 618
Membership notes, 105, 236, 310, 425, 529, 617
Popular science lecture, Some observations in Alaska (Taylor), 105
Presentation of Elliott Cresson medal to John A. Brashear, 99
Presentation of Elliott Cresson medal to John Fritz, 232
Presentation of Elliott Cresson medal to Edward Weston, 99
Presentation of Elliott Cresson medal to Harvey W. Wiley, 101
Proceedings of the stated meeting, Dec. 21, 1910, 102; Jan. 18, 1911, 233; Feb. 15, 1911, 304; March 15, 1911, 422; April 19, 1911, 519; May 17, 1911, 615
School of Mechanic Arts, Annual report of the director, 524
School of Mechanic Arts, Closing exercises, 520
Sections, Proceedings of meetings, 103, 234, 310, 423, 527, 616
Standing Committee, 1911, 304
FRANKLIN, W. S.: Dielectric stresses from the mechanical point of view, 245
Franklin-Adams Counties, Penna., The copper deposits of (Wherry), 151
GARDNER, HENRY A.: Value of certain paint oils, 55
GARDNER, WALTER M.: Vacuum tube lighting (correspondence), 111
Gaseous densities, The application of the Archimedean principle to the exact determination of (Jacquerod and Tourpaian), 91
GEBHARDT, GEORGE FREDERICK: Properties of dry, saturated and unsaturated air; with application to cooling-tower and evaporative surface condenser calculations, 165
HECKEL, G. B.: Materials of paint manufacture, 599
HEPBURN, JOSEPH SAMUEL: Recent progress in the chemistry of the terpenes and camphors, 179
HEPBURN, JOS. S.: The handling, transportation, and storage of perishable foodstuffs. A review of the work of the U. S. Food Research Laboratory, 585
HERING, CARL: Simplicity in the measures of physical quantities, 129
HERING, CARL: The stretching of a conductor by its current, 73
HERRICK, CHEESMAN A.: Remarks at the conclusion of the work of the Franklin Institute School of Mechanic Arts, 521
Honors by the Franklin Institute, 113
HUNGERFORD, CHURCHILL: Water filtration for industrial purposes, 261
Iron, Conservation of (Cushman), 345
JACQUEROD, A., and M. TOURPAIAN: The application of the Archimedean principle of the exa determination of gaseous densities, 91
KIMBALL, HERBERT H.: Some causes of variation in the polarization of sky light, 333
Lamps, New metallic filament (Merrill), 391
Light, sky, Some causes of variation in the polarization of (Kimball), 333
LYON, T. LYTTLETON, and JAMES A. BIZZELL: The relation of certain non-leguminous plants to the nitrate content of soils, I, 205
MARVIN, C. F.: Upon the construction of the Wheatstone bridge

for electrical resistance thermometer, 439
Measures of physical quantities, Simplicity in the (Hering), 129
MERRILL, G. S.: New metallic filament lamps, 391
MILLER, C. F.: The polarization of Roentgen rays from an anticathode of silver, 457
MOORE, D. MCFARLAN: Vacuum tube lighting (correspondence), 111

NERNST, W.: Introduction to certain fundamental principles of modern physics, 501
NORRIS, GEORGE L.: Vanadium alloys, 561

Oils, Paint, Value of certain (Gardner), 55

Paint manufacture, Materials of (Heckel), 599
PEARSON, WILLIAM A.: The preparation and testing of drugs, 415
Photography, Balloon, Notes on the history of (Dolezal), 301
Physics, modern, Introduction to certain fundamental principles of (Nernst), 501
Plants, non-leguminous, Relation of certain, to the nitrate content of soils (Lyon and Bizzell), 1, 205
Publications received, 110, 241, 314 429, 533, 621
Pumps, centrifugal, Notes on the design of, (Akimoff, N. W.), 497

Roentgen rays, The mean depth at which, originate within a silver target (Davey), 277
Roentgen rays, The polariation of, from an anticathode of silver (Miller), 457
SCHREINER, OSWALD, and EDMUND C. SHOREY: Soil organic matter as material for biochemical investigation, 295

SHOREY, EDMUND C., and OSWALD SCHREINER: Soil organic matter as material for biochemical investigation, 295
SLOCUM, S. E.: A general formula for the shearing deflection of beams of arbitrary cross section, either variable or constant, 365
Soil organic matter as material for biochemical investigation (Schreiner and Shorey), 295
Soils, The relation of certain non-leguminous plants to the nitrate content of (Lyon and Bizzell), 1, 205
STEINMETZ, CHAS. P.: Some unexplored fields in electrical engineering, 537
Stresses, Dielectric, from the mechanical point of view (Franklin), 245

Terpenes and camphors, Recent progress in the chemistry of the (Hepburn), 179
Thermometer, Electrical resistance, Upon the construction of the Wheatstone bridge for (Marvin), 439
TOURPAIAN, M., and A. JACQUEROD: The application of the Archimedean principle to the exact determination of gaseous densities, 91
TURNER, WALTER V.: The air-brake as related to progress in locomotion, 17

U. S. Food Research Laboratory, A review of the work of the (Hepburn), 585

Vacuum tube lighting (Gardner and Moore), 111
Vanadium alloys (Norris), 561
VIGNON, LEO: The influence of chemical affinity in certain phenomena called adsorption, 87

Water filtration for industrial purposes (Hungerford), 261
Wheatstone bridge for electrical resistance thermometer, Upon the construction of the (Marvin), 439
WHERRY, EDGAR T.: The copper deposits of Franklin-Adams Counties, Pennsylvania, 151
WILEY, HARVEY W.: Applications of chemistry to public welfare, 47

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ANNOUNCEMENTS
OF THE
FRANKLIN INSTITUTE

	PAGE
Officers and Standing Committees	xii
Membership	xiii
Awards and Premiums	xiv
Elliott Cresson Medal	xv
John Scott Legacy, Medal and Premium	xvi
Boyden Premium	xvii
Journal Contributions	xviii
Library	xix
Journal and Indices	xix
School of Mechanic Arts	xx, xxvii